HUNGARIAN UNIVERSITY OF AGRICULTURE AND LIFE SCIENCES

URBAN PUBLIC PARK DEVELOPMENT AND DISTRIBUTIONAL EQUITY ASSESSMENT - A CASE STUDY OF ZHENGZHOU, CHINA

THE Ph.D. DISSERTATION

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LIST OF ABBREVIATIONS

UPP - Urban Public Park

UGS - Urban Green Space

2SFCA - Two-Step Floating Catchment Area

GIS - Geographic Information System

PPGIS - Public Participation GIS

API - Application Programming Interface

AOI - Area of Interest

PRC - People’s Republic of China

HMM - High-supply Medium-demand Medium-accessibility type

LML - Low-supply Medium-demand Low-accessibility type

HLH - High-supply Low-demand High-accessibility type

MHL - Medium-supply High-demand Low-accessibility type

1 INTRODUCTION

1.1 Background and context

1.1.1 Background

(1) The role of urban parks in enhancing urban quality

With the development of cities, urban parks have gradually developed into an integral part of the urban environment and enhanced urban quality by providing a multitude of benefits across various dimensions including social, environmental, and economic aspects (Chiesura 2004, Tempesta 2015). Socially, as essential public spaces, urban parks play a vital role in enhancing the quality of urban life by fostering physical and mental well-being of urban residents, social interaction, community cohesion, and connection with nature (Grilli et al. 2020, Mansor et al. 2012, Peters et al. 2010). As basic components of the urban green infrastructure, urban parks contribute to environmental sustainability by providing a wide range of ecosystem services to cities (Veerkamp et al. 2021). They enhance biodiversity by serving as habitats for diverse flora and fauna. Moreover, urban parks help mitigate various environmental issues, such as managing stormwater runoff, reducing the urban heat island effect, and improving air quality (Wolch et al. 2014, Yao et al. 2022). Economically, urban parks make cities more attractive to both visitors and investors by improving their overall aesthetics and service value, thereby stimulating tourism and enhancing property values in nearby areas, boosting the economic vitality of cities (Harnik 2009).

(2) The impact of inequitable access and use of urban parks

Equitable access and use of urban parks refer to providing fair and inclusive opportunities for all individuals from diverse backgrounds to enjoy and benefit from urban parks. The inequitable access and use of urban parks can have significant impacts on individuals and communities. When some populations lack nearby parks or have poorly maintained ones, they are deprived of the benefits associated with physical activity, relaxation, social interaction, and exposure to nature, which can contribute to physical and mental health issues (Mowen et al. 2007, Slater et al. 2020). Additionally, limited access to and use of parks can lead to lower satisfaction and perception of parks, resulting in feelings of exclusion and isolation among disadvantaged groups. When certain communities are denied access to well-maintained parks, they miss out on opportunities for social interaction, community engagement, and cultural events, thereby hindering residents' ability to connect with and develop a sense of belonging to their communities or city (Shukur et al. 2012). Overall, these disparities can further reinforce social inequality and exacerbate existing divisions within communities and cities.

(3) The effect of equity-oriented urban park planning

Equity-oriented urban park planning is an integrated approach that recognizes the significance of planning, designing, and managing urban parks to yield beneficial impacts on the overall urban quality. This approach aims to prioritize the provision of equitable park access for people of various capabilities, thereby extending the physical, mental, and social benefits of parks to a wider spectrum of individuals and communities. Furthermore, equity-oriented urban park planning embodies the integration of environmental justice and urban sustainability, aiming to enhance access to natural spaces and environmental advantages for marginalized communities. Equity-oriented urban park planning prioritizes inclusive and participatory approaches that engage diverse stakeholders in the decision-making and management processes. Engaging community members helps to build social connections and fosters a sense of ownership and belonging (Shuib et al. 2015). Tailoring park programming to the community's preferences and needs not only boosts park satisfaction and perceptions, leading to increased usage and enjoyment (Chiesura 2004, Rigolon 2016) but also ensures that park decisions are informed by local insights and knowledge, aligned with community values, and reflect the specific cultural context.

1.1.2 Context

(1) The approach to pursuing the "Park City" vision and implementing "nature-based solutions" within Chinese and European policies, respectively

The "Park City" initiative in China presents an ideal model for urban construction and development, targeting a series of environmental and social problems arising from China's rapid urbanization while responding to demands for a greener, more livable environment. This initiative is built upon the principles of "ecological civilization" and "people-centered", striving to foster a harmonious relationship between citizens, parks, and the city, thereby advocating for the integration of urban park systems within urban fabric (Wu et al. 2018, Zou et al. 2020). The principle of "people-centered" highlights the importance of publicness, accessibility, and equity in urban parks (Li et al. 2018). In parallel, "nature-based solutions" within European environmental policy aim to mitigate various environmental, social, and economic challenges through the sustainable management and application of natural processes. Urban parks are recognized as a key example of "nature-based solutions" for fostering sustainable urban development, given their potential to enhance the social cohesion, climate resilience, and economic competitiveness of cities (European Commission 2015). Together, these initiatives and strategies advocate for effective, sustainable, and equitable implementation of urban parks, highlighting their role as critical green infrastructure and public service facilities towards ecological and social well-being in the face of urban challenges.

(2) The lack of recognition concerning the relationship between the distribution of urban

parks and their equity

In discussions of equity, it is commonly posited that public services should be distributed equally. However, this first notion encounters limitations when applied to urban parks. Firstly, equality is not a coherent concept when subjected to systematic analysis of park indicators (Lucy 1981). Equal allocation of park resources does not necessarily ensure equality in the outcomes of park services. Moreover, equal distribution of urban parks is often deemed less desirable when compared to other equity principles, such as need-based allocation. Equity itself is a complex concept, signifying the fairness or justice in a given situation or distribution. Equity can be achieved when society reaches a consensus on what is “fair” or “just” (Talen 1998a). Furthermore, the criteria for measuring distributional equity are historical and dynamic, reflecting evolving norms and values within specific societal contexts. Despite its fundamental importance in urban park planning and assessment, integrated analyses examining the development and evolution of distributional equity’s connotations and criteria remain scarce. This gap, motivated by growing concerns about marginalization within urban social spaces, underscores the need for a more systematic exploration and comprehensive understanding of how the equity of urban parks is conceptualized and operationalized within urban planning frameworks.

(3) The phenomenon of inequity in the development of urban parks during the rapid urbanization process

In the broader context of global urbanization, cities worldwide are increasingly confronted with a series of social and environmental challenges. Particularly in China, major cities such as Zhengzhou have experienced extremely rapid urbanization in recent decades, leading to social differentiation, spatial segregation, and environment issues (Li 2021, Wu et al. 2014). Despite the recognition of urban parks as essential public services and green infrastructure with numerous benefits, inequities in their distribution persist, disproportionately affecting certain communities and groups. For example, significant disparities in park distribution exist between newly expanding urban zones and older inner-city areas in Zhengzhou (Shi 2021). These inequities can be attributed to varying levels of urban ecological concerns across distinct contexts of urban environments and differing levels of support for urban park construction depending on socio-economic status. Additionally, the criteria for planning and assessing urban park distribution often diverge at various stages of urban development and planning. Moreover, the rapid pace of urbanization often prioritizes the maximization of efficiency over equity, exacerbating these disparities. In recent years, urban regeneration and social sustainability have become critical aspects of urban planning and development (Colantonio et al. 2010). Equity-oriented planning and governance of urban parks can play a pivotal role in promoting social cohesion and enhancing environmental justice by creating inclusive, equitable, and resilient urban environments, thus contributing to social and environmental sustainability.

1.2 Concepts of terminology

(1) Urban public parks (UPPs)

UPPs, as recognized today, initially emerged in mid-19th century Britain, a period marked by profound societal changes due to industrialization and urbanization, along with the rise of democratic ideals. The subsequent public park movement, gaining momentum in North America during the mid to late 19th century, played a crucial role in promoting the development of UPPs. A comprehensive overview of the publicness development of UPPs is provided in Section 2.1. However, due to varied interpretations and the dynamic connotations of urban parks, there remains no unified concept of UPPs. For the purposes of this research, UPPs are defined as designated open spaces within urban environments, primarily designed for the recreation and leisure of the general public and incorporating integrated social, environmental, and economic functions. These areas are publicly accessible and typically managed by public institutions. Notably, in this research, the scope of UPPs is delineated by two key characteristics: free access and adequate size. Free access eliminates the barrier of admission fees, facilitating an equity study on park accessibility, while adequate size ensures that a variety of recreational and leisure activities can be accommodated, and multiple functions effectively served.

(2) Distributional equity

Distributional equity, a component of the broader equity framework, distinguishes itself from the other two dimensions, namely procedural equity and contextual equity. It focuses on evaluating whether the outcomes of resource allocation are equitable among different socio-spatial areas or socioeconomic groups. The core of the equity debate in urban planning lies in the specific distribution of public benefits among members of society during the resource allocation process (Rawls 1971). Distributional equity is acknowledged as a subjective and relative concept, influenced by the existence of varied social norms and moral judgments (Van Wee et al. 2011). What one group considers equitable may be viewed as inequitable by another, leading to an ongoing debate over its various interpretations. Furthermore, the measurement criteria of distributional equity are historical and dynamic, deeply rooted in specific societal contexts, thus demonstrating high practicality while maintaining empirical relevance (Zhang et al. 2019, Zhou 2020). Section 2.2 thoroughly examines the key stages and modes of distributional equity assessment in UPPs drawing on the developmental characteristics of societal contexts and the corresponding public values advocated.

(3) Spatial accessibility

In this research, the concept of accessibility is framed within the context of relative space and contrasted with the notion of isolation. It is inherently interconnected with equity, due to the comparative significance of its values within a given region. This understanding distinguishes it from other forms of accessibility, such as those from geometric or barrier-free perspectives. Hardly any book or paper on urban and regional affairs fails to allude, in some way or another, to the notion of accessibility (Pirie 1979). Nevertheless, accessibility is a slippery concept, manifesting different interpretations depending on the specific problems and contexts in which it is applied (Gould 1969, Handy et al. 1997). Some scholars consider accessibility as the number or density of opportunities that can be reached within certain spatial range (Handy et al. 1997, Wachs et al. 1973). Others view accessibility as the ease with which spatial impedance can be overcome (Allen et al. 1993, Ingram 1971, Maćkiewicz et al. 1996). In Hansen's work (1959), accessibility is defined as the potential of opportunities for interaction, offering a measure of the intensity of the possibility of interaction that extends beyond a mere measure of the ease of interaction. These varied interpretations have led to diverse accessibility measures for urban parks, which is comprehensively analyzed in Section 2.3.

1.3 Aims and questions

1.3.1 Research aims

The main aim of this research is to synthesize the basic historical development of UPPs worldwide and in China, and to explore the assessment and measurement of equity in their distribution, specifically concentrating on an in-depth examination of UPPs in Zhengzhou, China (***Figure 1.1***).

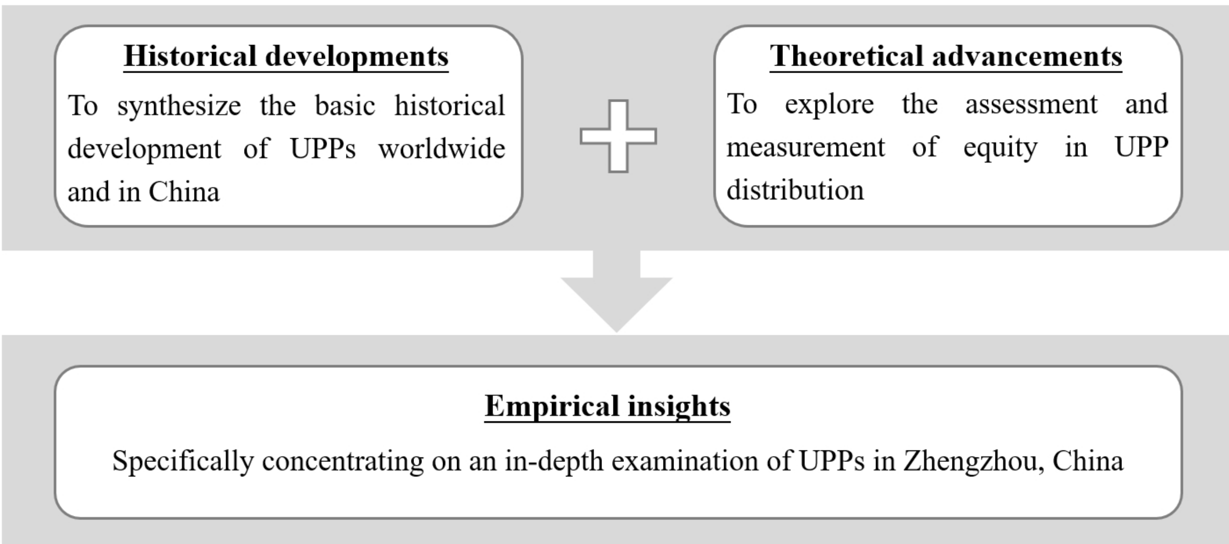

Figure 1.1: Research aims (Source: Author).

The objectives of the dissertation are as follows:

a) To synthesize general origins and basic development of UPPs both worldwide and in China

b) To identify the developmental process and characteristics of distributional equity assessment in UPPs

c) To develop an appropriate accessibility method for UPPs through a comprehensive review of accessibility measurement

d) To provide empirical analysis and evaluation of UPP development from a historical and local point of view

e) To present empirical measurement and examination of spatial patterns of accessibility and equity in UPPs

1.3.2 Research questions

Linked to these research objectives, the dissertation addresses the following related questions:

a) What are the general origins of UPPs, and how has their development unfolded both worldwide and in China?

- What are the historical roots of parks within cities?
- What are the basic stages of publicness development in UPPs worldwide?
- What features characterize the emergence and development of UPPs in China?

b) What are the developmental process and characteristics of distributional equity assessment in UPPs?

- How has distributional equity assessment advanced by drawing on the developmental characteristics of societal context and corresponding public values advocated?
- What are the developmental characteristics of distributional equity models in the assessment subjects and measurement criteria?
- What transformations occur in measuring between parks and residents of distributional equity models?
- What are the relationships of distributional equity models with contextual equity and procedural equity?

c) What are the interpretations and measures of spatial accessibility for UPPs, and how can an appropriate accessibility method be specified?

- What is the relationship between accessibility and equity, and how can spatial accessibility be interpreted?
- What are the characteristics and conceptual differentiation of the primary accessibility measures for urban parks?

- What is the two-step floating catchment area (2SFCA) model, and what major extensions have been made to it?
- How can the 2SFCA method be improved through model optimization and data refinement to measure the accessibility of UPPs?

d) How to evaluate and what are the developmental phases, trends, and strategies of Zhengzhou's UPPs?

- What phases have UPPs in Zhengzhou gone through according to the city's developmental stages and green space developmental opportunities?
- What are the developmental trends of UPPs in Zhengzhou from the perspective of implementation approaches, spatial layout, functions and uses, and sustainability?
- What developmental strategies can be introduced in Zhengzhou to tackle existing problems?

e) How to examine and what are the spatial patterns of accessibility and equity in Zhengzhou's UPPs?

- How to effectively measure spatial accessibility and assess distributional equity in UPPs?
- What are the characteristics and causes of accessibility distribution both at the neighborhood scale and urban ring scale in Zhengzhou?
- What corresponding solutions can be formulated in Zhengzhou to mitigate spatial disparities?

1.4 Research methodology

The research methodology depicted in ***Figure 1.2*** comprises two parts: basic research relying on a theoretical approach and applied research based on an empirical approach. The first part involves a literature review and investigation methods, primarily adopting inductive and qualitative research perspectives. The second part employs a case study and investigation methods, integrating both inductive and deductive reasoning, and combining qualitative with quantitative analyses. Specifically, a variety of data analysis methods, such as historical analysis, content analysis, and statistical analysis, are applied to both primary and secondary sources utilizing techniques mainly within MS Excel and ArcGIS.

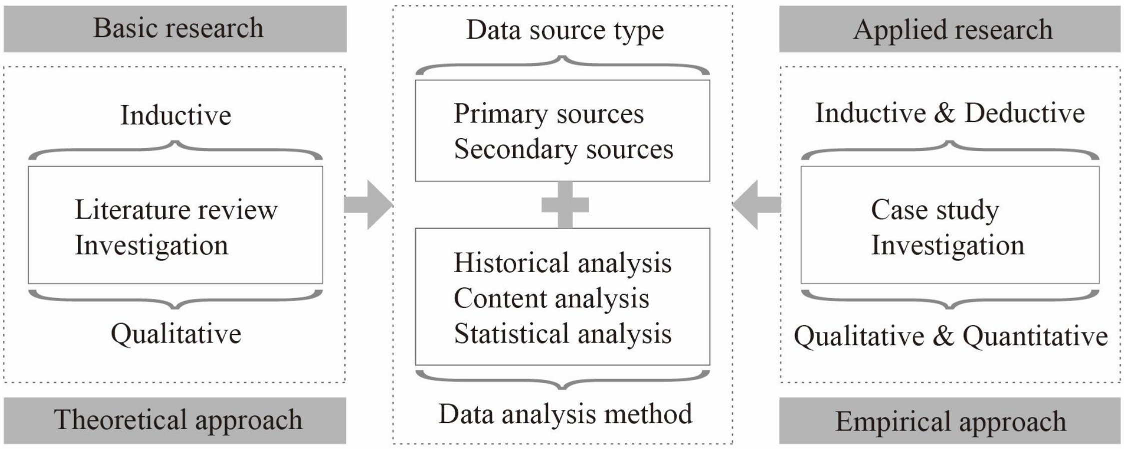

Figure 1.2: Research methodology (Source: Author).

1.4.1 Data collection methods

(1) Literature review

In the beginning of the research process, an extensive literature review was carried out, relying on secondary data such as textbooks, reviews, and bibliographies sourced from multiple scientific databases. This review aimed to scrutinize the historical development, and assessment and measurement of distributional equity in UPPs. Then, an examination of literature pertaining to the origins and development of urban parks, distributional equity assessment in UPPs, and accessibility measurement for assessing equity were undertaken. Through the systematic reading, sorting, and analysis of diverse literature, the main historical developments of UPPs and their theoretical advancements of distributional equity were identified. In general, this research phase serves to establish a theoretical foundation and a source of ideas for further research.

(2) Case study

A case study was employed as the empirical approach to advance applied research. The selection of Zhengzhou, China, as the case was grounded in its significant role among Chinese cities, the global representative of rapidly urbanizing regions, and the typicality observed in its UPP development in the Chinese context. Aligned with the research aims and framework, specific research questions were formulated for the case study. Firstly, how to evaluate and what are the developmental phases, trends, and strategies of Zhengzhou's UPPs? Secondly, how to examine and what are the spatial patterns of accessibility and equity in Zhengzhou's UPPs? Through in-depth fieldwork and extensive online investigation, various sources of data were collected. Subsequently, a detailed data analysis was employed to identify the developmental process and spatial patterns of UPPs in Zhengzhou, China. This comprehensive case study provides deeper insights into the research subject.

(3) Investigation

The investigation employed two primary methods: online investigation and fieldwork. The online investigation was undertaken to collect various available materials related to the basic development and distributional equity of UPPs, with a specific focus on Zhengzhou, China. These materials comprised statistical yearbooks, census data, historical records, and other texts and images sourced from the websites of libraries, archives, and municipality. Additionally, digital maps, remote sensing datasets, and other social big data for the case study were obtained from online data platforms. The fieldwork conducted within the case study area aimed to gather on-site information, including details on park category and quality, and park functions and uses. The fieldwork involved comprehensive documentation through observation, measurements, and recording including detailed notes and photographs. The data acquired from these investigations facilitates both qualitative and quantitative analyses.

1.4.2 Data analysis methods

(1) Historical analysis

Historical analysis involves the systematic examination and interpretation of historical process and trends of UPPs. The objective is to gain a comprehensive understanding of how UPPs have developed and how distributional equity considerations have evolved over the years, in a broader context and specifically within Zhengzhou, China. Firstly, a chronological timeline of significant events and milestones in the development of UPPs was created. And historical events within the broader societal context, considering factors such as urbanization level, public value governance, government policies that influenced park development or equity were analyzed. Then historical urban policies and planning related to parks were analyzed to understand how public governance and government decisions shaped the development of UPPs and whether there have been advances in their distributional equity. Moreover, the evolution of UPPs over time in Zhengzhou was assessed by exploring aspects such as implementation approaches, spatial layout, and function and uses. The conclusions drawn from the historical analysis provide informed insights that contribute to current and future urban planning strategies.

(2) Content analysis

Content analysis is employed to systematically analyze the texts and images concerning the development and distributional equity of UPPs within both a broader context and the specific area of Zhengzhou, China. The analysis aligns with research objectives, intending to comprehend the historical development of UPPs, identify the evolution of distributional equity assessment in UPPs, review spatial accessibility measurement for assessing equity in the distribution of UPPs, analyze the developmental process and characteristics of UPPs in Zhengzhou, and examine spatial patterns of accessibility and equity of these parks. Content sources such as phrases and images were considered as the analysis unit, and a coding scheme was formulated reflecting the variables of interest, including park developmental phases, distributional equity models, spatial accessibility measures and so on. On one hand, qualitative analysis was undertaken to interpret the theme and meaning behind the coded content, involving identifying interpretations, patterns, relationships, or trends related to the development and distributional equity of UPPs. On the other hand, quantitative analysis was conducted to primarily assess the quantity of parks or variables associated with parks. Finally, the results were presented in a comprehensive manner, combining quantitative and qualitative insights.

(3) Statistical analysis

A combination of statistical analysis methods was utilized, encompassing descriptive statistics, spatial analysis, and cluster analysis, to examine spatial patterns of accessibility in UPPs within Zhengzhou, China. Descriptive statistics involved summarizing and describing the main features, specifically mean and standard deviation measures, concerning neighborhood accessibility within each urban ring. It offered insights into its central tendency and variability of the distribution. Catchment area analysis was applied to analyze and interpret neighborhood accessibility of UPPs through geographic information system (GIS) techniques. K-means clustering was performed to effectively partition data into clusters based on similarity and differences. Major factors with respect to supply, demand, and accessibility were selected to delineate various types of park accessibility and their corresponding regions. As a crucial tool in quantitative research, statistical analysis helps derive meaningful insights from data, facilitating informed decision-making grounded in statistical evidence.

1.5 Framework for the dissertation

1.5.1 Research framework

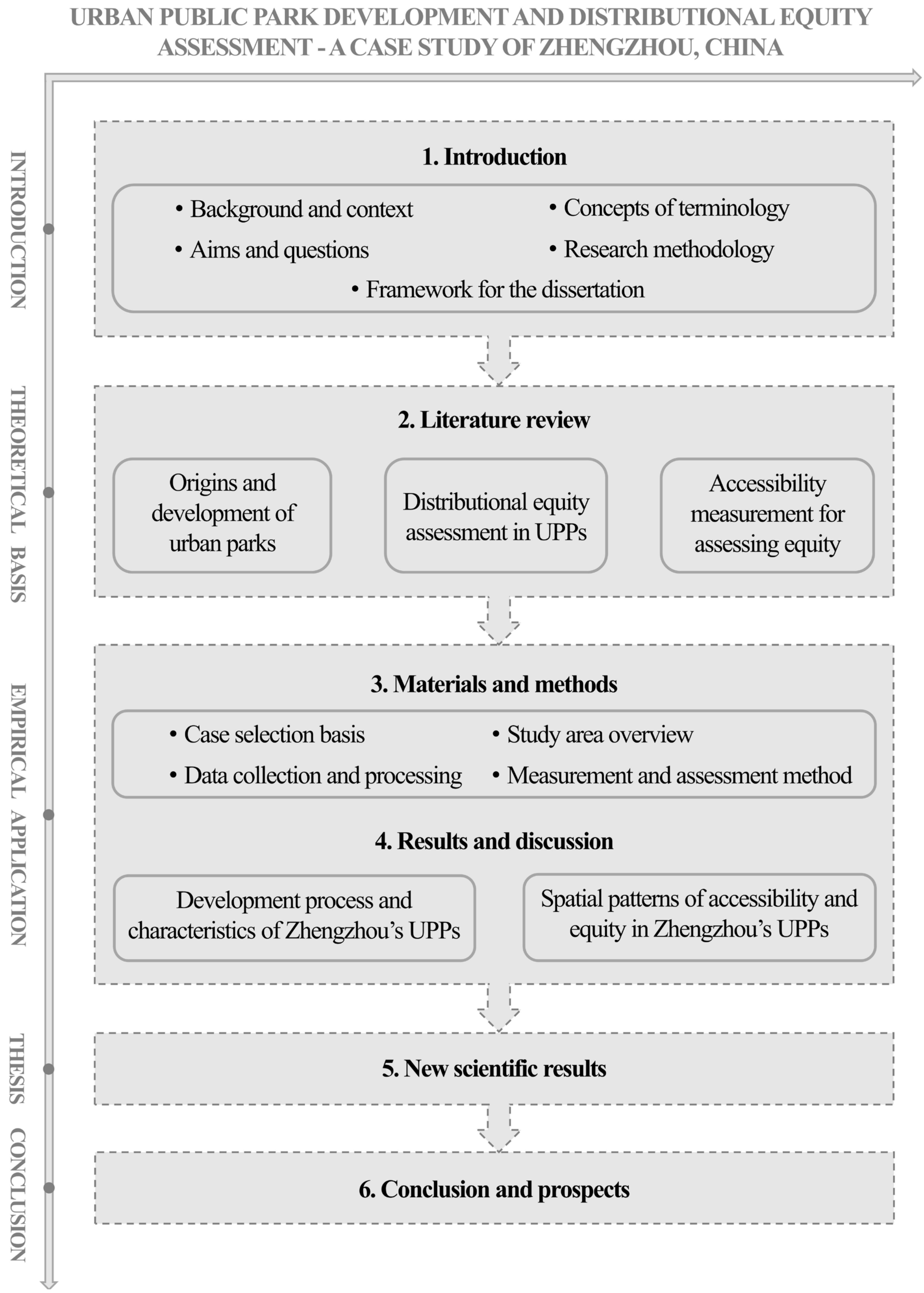

Figure 1.3: Research framework (Source: Author).

1.5.2 Research outline

The dissertation is structured in six chapters.

Chapter 1 sets the stage for the dissertation by providing essential background and context of the research. Key terms are clearly defined, laying the groundwork for a thorough understanding. It then articulates the research aims and questions, as well as the methodology employed. Moreover, the chapter establishes the overall framework for the dissertation.

Chapter 2 explores the theoretical aspects concerning the development and equity of UPPs. The first part synthesizes general origins and basic development of UPPs both worldwide and in China. The second part illuminates the equity framework and explores the evolution of distributional equity assessment in UPPs. The third part introduces the spatial accessibility measurement for assessing equity in the distribution of UPPs.

Chapter 3 provides the context for the case study on UPPs in Zhengzhou, China. It presents the basis for selecting this case and offers an overview of the study area, particularly focusing on the central urban area of Zhengzhou. The chapter then describes the data collection and processing procedures employed. Finally, it introduces the method used for measuring accessibility and assessing equity, with a specific focus on the improved 2SFCA method.

Chapter 4 focuses on a case study of UPP development and distributional equity in Zhengzhou, China. The chapter first provides an overview of UPP development in Zhengzhou, outlining its developmental phases and trends. Subsequently, it examines the spatial patterns of accessibility and equity of UPPs within its central urban area and concludes with practical recommendations.

Chapter 5 presents new scientific results, focusing on theoretical advancements and methodological innovations for distributional equity assessment of UPPs. In addition, it strengthens the practical significance of these insights by grounding them in empirical study findings from Zhengzhou, China.

Chapter 6 summarizes the main findings of the research, reflecting on the initial aims and questions and evaluating their broader implications. Furthermore, it presents two recommendations aimed at advancing further research on distributional equity in UPPs.

2 LITERATURE REVIEW

2.1 Origins and development of urban parks

This section aims to synthesize the origins and basic development of UPPs, both worldwide and within China. It begins by tracing the historical roots of urban parks to understand their initial inception. The discussion then transitions to an analysis of the broader development of urban parks worldwide, focusing on the aspect of publicness that shape their accessibility and functionality. Moreover, this section delves into the specific emergence and development of urban parks in China, highlighting the establishment of the earliest urban parks and detailing their subsequent developmental phases. Through this structured examination, the research can shed light on the historical and societal contexts that have influenced urban park development worldwide and in China, illustrating how these green open spaces have evolved to meet the changing needs of urban life over time.

2.1.1 General origins of urban parks

Urban parks are widely recognized as some of the most crucial and emblematic elements of urban open spaces. The concept of urban parks generally originates from two distinct historical sources (Wu et al. 2018), as detailed in ***Table 2.1***. The first source includes the private open spaces in historical cities, which were typically residential gardens owned by royalty or nobility. Examples of these are Hyde Park in London, UK, and the Summer Palace in Beijing, China[1], for royal gardens, and Villa Borghese Gardens in Roma, Italy, and Lingering Garden in Suzhou, China[2], for noble gardens. These spaces were typically reserved for the privileged class and not accessible to the public. The second source encompasses public open spaces within historical cities or their peripheries. These include natural scenic areas like Hangzhou West Lake Attraction in China[3], open spaces associated with religious activities such as the sacred groves adjacent to temples in Ancient Greece or Egypt, and other open spaces designated for specific public purposes like Plato's Academy and botanical gardens. These areas primarily offered limited public service benefits or served special functions with corresponding design. Some of today's urban parks have developed from these historical foundations, undergoing fundamental transformations to meet the evolving needs of diverse societal contexts.

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[1] World Heritage Convention website (https://whc.unesco.org/en/list/880/). Accessed May 2023.
[2] World Heritage Convention website (https://whc.unesco.org/en/list/813/). Accessed May 2023.
[3] World Heritage Convention website (https://whc.unesco.org/en/list/1334/). Accessed May 2023.

Table 2.1: Roots of urban parks within cities in history (Source: Author).

Root	Categories	Feature
Private open spaces	**Royal gardens** • Hyde Park in London, UK, • Summer Palace in Beijing, China **Noble gardens** • Villa Borghese Gardens in Roma, Italy • Lingering Garden in Suzhou, China	Typically reserved for the privileged class and not accessible to the general public
Public open spaces	**Natural scenic areas** • Hangzhou West Lake Attraction in China **Open spaces associated with religious activities** • Sacred groves adjacent to temples in Ancient Greece or Egypt **Other open spaces designated for specific public purposes** • Plato's Academy and botanical gardens	Primarily offering limited public service benefits or serving special functions with corresponding design

2.1.2 Publicness development of urban parks

The earliest instances of so-called "public parks" originated from the transformation of royal and noble gardens into spaces accessible to the general public. This transition gained prominence following significant societal changes, particularly those in Britain during the 17th century, which led to the opening of spaces like Hyde Park and St James's Park in London (Larwood 1874). Subsequently, across continental Europe, notable examples include the Jardin des Tuileries in Paris, which was the first royal garden in France to be opened to the public. These moves democratized access to what had previously been exclusive royal grounds to some extent, significantly influencing the subsequent development of public parks in cities worldwide. However, the public nature of these parks, essentially private spaces, was initially restricted in access, either in terms of opening time or spatial extent, primarily catering to specific social classes of visitors (Luca 2016).

There is a long tradition of setting aside green spaces for public use in continental Europe, although in the early days this was largely permissive and unorganized practice. It is particularly so in Germany, where public gardens date back to the late 18th century. One of the earliest and largest gardens for public use was the Englischer Garten along the River Isar in Munich, deliberately designed by Friedrich Ludwig von Sckell under the supervision of Benjamin Thompson (Count Rumford) (Chadwick 1966). Officially opened to citizens in 1792, the garden spanned three miles along the riverside and was laid out in the English style, featuring a Chinese tower (***Figure 2.1***).

Similarly, the Maksimir Park in Zagreb, Croatia, founded in 1787, is the oldest large public park in Southeastern Europe. It was named "Maksimir" in honour of Bishop Vrhovac, who envisioned the creation of a large park for the citizens of Zagreb on the place of an old bishop's forest. The park was officially opened to the public in 1794[4]. Initially conceived in a French Baroque style, it was later designed as a pastoral and recreational area inspired by the English landscape garden style (***Appendix 1***). Another early example of public gardens is the Városliget (City Park) in Budapest, Hungary. At the beginning of the 19th century, the New Town Forest (Stadtwaldchen), despite its unconstructed wilderness, was already a popular destination for city dwellers seeking walks or excursions. In 1813, an international design competition was launched by the Royal Beautification Commission to arrange the area. The plan by Heinrich Nebbien (***Appendix 2***) to create a real public garden covering approximately 11.6 hectares was later realized, also in the English landscape garden style (Jámbor 2019).

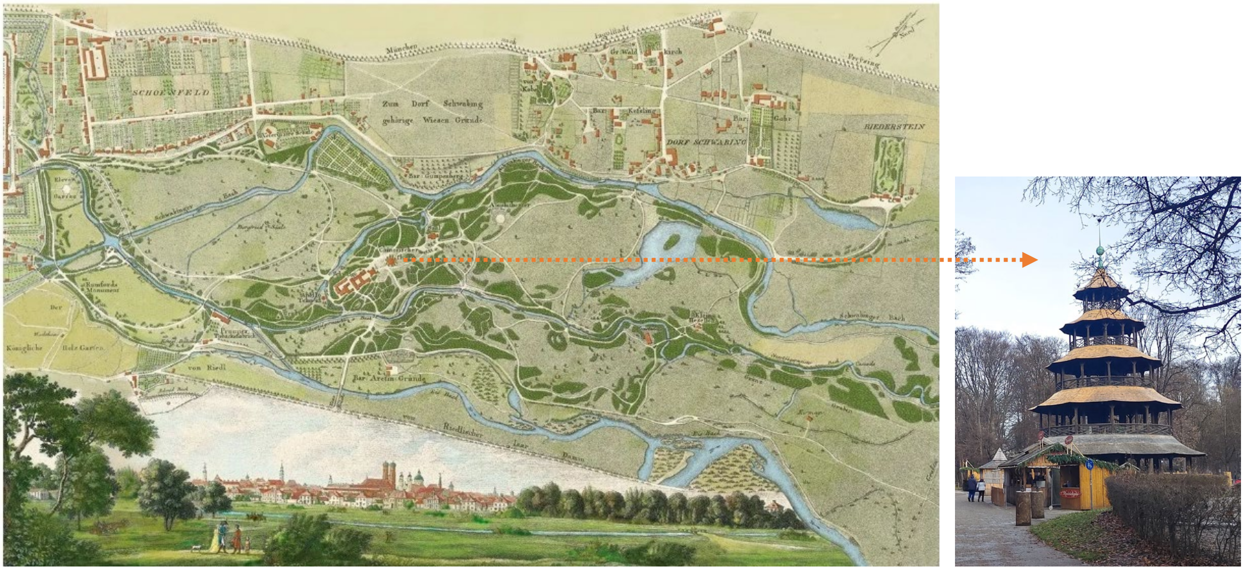

Figure 2.1: Englischer Garten in Munich in 1806 and Chinese tower in present day (Source: Franz Schiermeier Verlag München website[5] and Author, respectively).

With the onset of the industrial revolution and rapid urbanization, European cities in the latter half of the 18th century faced urban challenges such as overcrowding, environmental pollution, and epidemic diseases. This aroused public concern for health and a growing recognition of the social need for improved living conditions. During this period, public open spaces were advocated as an essential tool for urban governance due to their crucial role in improving the urban environment (Clark 1973). Additionally, influenced by the zeal for social reform, the creation of accessible

[4] Park Maksimir website (https://web.archive.org/web/20180318143450/http://www.park-maksimir.hr/maksimir_en/Maksimir_povijest_parka_en.htm). Accessed May 2023.
[5] Franz Schiermeier Verlag München website (https://www.stadtatlas-muenchen.de/m-1806-englischer-garten). Accessed May 2023.

landscapes within cities for public use was seen as a right of the general public. Consequently, the British government initiated the development of modern UPPs. In 1847, Birkenhead Park in Liverpool, designed by Joseph Paxton (***Figure 2.2***), was officially and fully opened to the public. This event marked the first instance of an urban park laid out with public funds and freely accessible to people of all social classes. This milestone marked a significant step in the emergence of modern public parks. Subsequently, numerous urban parks were developed across the UK, serving as inspiration for cities worldwide. It can be said that these parks, laid out since that time, have significantly influenced the image of modern cities.

Figure 2.2: Joseph Paxton's plan and present imagery of Birkenhead Park in Liverpool (Source: Birkenhead Park website[6] and Google Earth Imagery, respectively).

The development of urban parks in the mid to late 19th century can be attributed to the growing movement advocating for public parks in North America. This movement arose in response to the accelerated urbanization and deterioration of urban environments resulting from population growth. Central Park in New York stands as a landmark achievement of this urban park movement. Inspired by the British concept of park democracy, it was initiated to provide a public space for recreation and leisure that was accessible to all. Designed by Frederick Law Olmsted and Calvert Vaux, Central Park (***Figure 2.3***) was opened to the public in 1858, covering over 341 hectares in the heart of Manhattan. It's worth mentioning that Olmsted stands out as the first potential reformer in recognizing the social significance of UPPs. From his perspective, park design was part of a larger social vision characterized by democratic ideals of community and equality and serving as a staunch opposition to the expansion of slavery (Menard 2010). Characterized by a naturalistic landscape, Central Park offers a rich variety of recreational facilities and activities, such as playgrounds, sports fields, a music hall, boating, and skating. Notably, it pioneered innovative traffic management by separating pedestrian and carriage pathways on different levels. Central Park serves as a green oasis amidst the bustling metropolis, promoting physical and mental well-

[6] Birkenhead Park website (https://birkenhead-park.org.uk/birkenhead-parks-conception-and-opening/). Accessed May 2023.

being while fostering a sense of community and connection with nature.

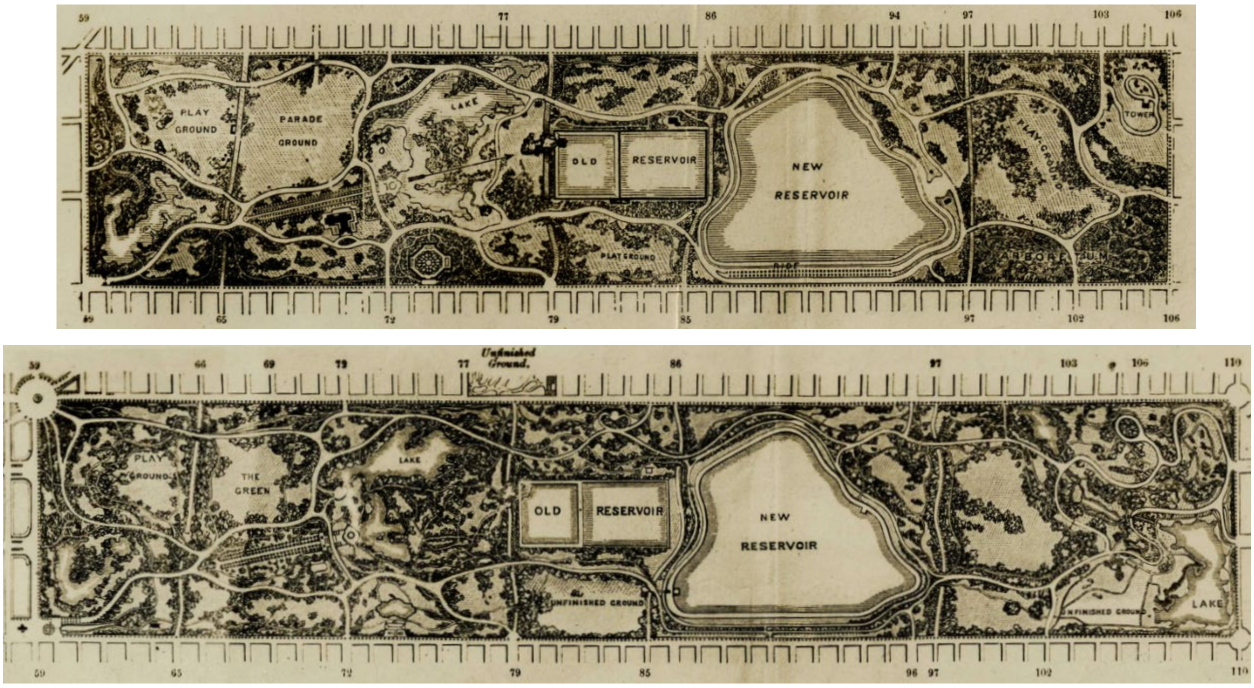

Figure 2.3: Original and modified "Greensward" plan of Central Park in New York by Olmsted and Vaux, 1858 and 1868, respectively (Source: 6sqft website[7]).

Moreover, the evolution of urban park construction has progressed from the consideration of individual parks to the planning of interconnected park clusters or complete park systems, exerting a profound influence on the shaping of urban landscapes. One of the most notable examples is the Boston Park System (***Figure 2.4***), conceived and planned by Frederick Law Olmsted during the late 19th century, often referred to as the "Emerald Necklace". Olmsted's idea of interconnecting urban green spaces (UGSs) marked a crucial moment in the development of urban parks, representing the germ of contemporary green infrastructure. Stretching across 16 km, the Boston Park System comprises nine distinct sections: Boston Common, Public Garden, Charlesbank Park, Commonwealth Avenue, Back Bay Fens, Jamaica Park, Muddy River, Franklin Park, and Arnold Arboretum (Zaitzevsky 1982). These parks and green spaces are interconnected through thoughtfully planned parkways, forming an integral parkway system that also serves as the skeleton of the city's spatial expansion. The Boston Park System not only offers effective solutions to environmental problems such as flooding and pollution but also provides residents and visitors with opportunities for outdoor recreation and leisure, cultural and educational experiences, community gathering and social cohesion, and nature exploration. Furthermore, it contributes significantly to urban planning and development endeavours.

[7] 6sqft website (https://www.6sqft.com/an-archive-of-24000-documents-from-frederick-law-olmsteds-life-and-work-is-now-available-online/). Accessed May 2023.

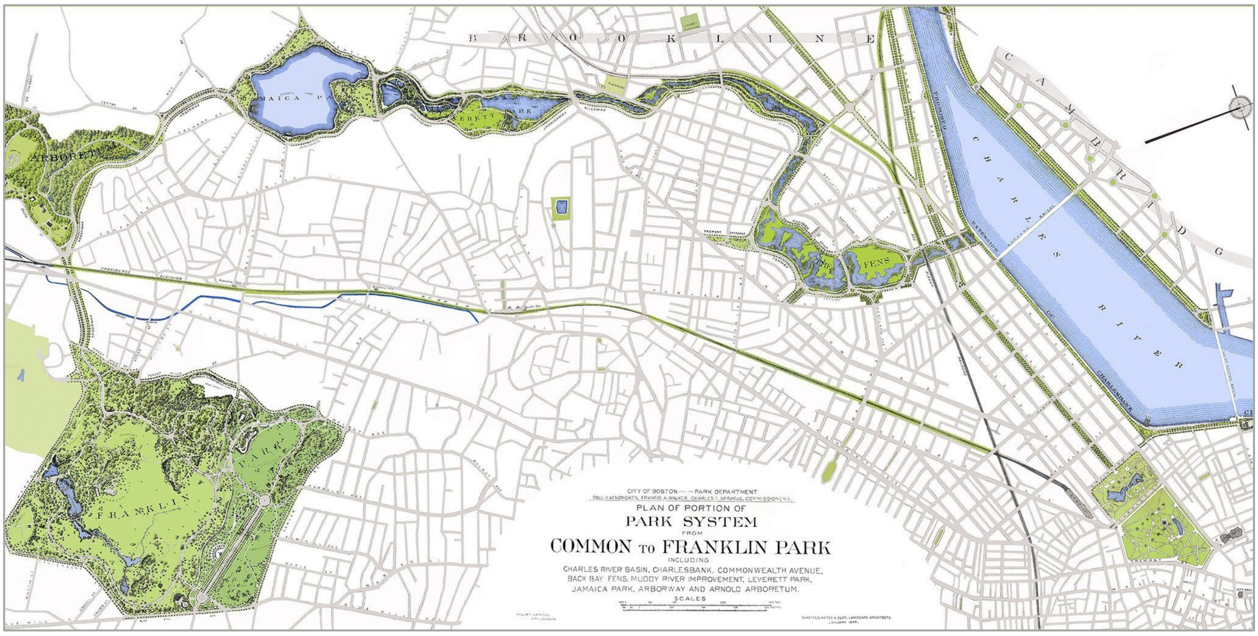

Figure 2.4: Boston Park System by Boston Parks Department & Olmsted Architects (Source: WardMaps website[8]).

UPPs, as recognized today, originated in the mid-19th century Britain, where they were conceived as a tool of urban governance to address the environmental challenges posed by industrialization and urbanization, coupled with the rise of democratic ideals. The subsequent public park movement, which gained momentum in North America during the mid to late 19th century, was critical in advancing the development of UPPs. In the mid-19th century, UPPs were created to provide space for physical activity, to make nature accessible to urban residents, to promote moral and visual education, and to help the social interaction among different social classes. As the century progressed, the role of parks expanded to highlight education in botany and arboriculture, and the infrastructure evolved from large open lawns to specialised activity grounds, such as sports fields and playgrounds (Conway 1991, Luca 2016). These modern public parks significantly differed from their historical predecessors in terms of roles, functions, and accessibility (***Table 2.2***). Nonetheless, the pioneering notion of publicness from earlier centuries was instrumental in influencing the development of modern public parks.

[8] WardMaps website (https://wardmapsgifts.com/products/emerald-necklace-common-to-franklin-park-boston-massachusetts-1894). Accessed May 2023.

Table 2.2: Comparison of publicness development in urban parks (Source: Author).

Period	Category	Feature
During 17th century	**So-called "public parks"** • Hyde Park in London, UK • St James's Park in London, UK • Jardin des Tuileries in Paris, France	• Transformation of royal and noble gardens into spaces accessible to the public • Restricted access, in terms of opening time, spatial extent, or social classes
Late 18th - early 19th century	**Early public gardens** • Englischer Garten in Munich, Germany • Maksimir Park in Zagreb, Croatia • Városliget in Budapest, Hungary	• Tradition of setting aside green spaces for public use • Largely permissive and unorganized practice
Since the mid-19th century	**Modern public parks** • Birkenhead Park in Liverpool, UK • Central Park in New York, US • Boston Park System, US	• Laid out and managed by public institutions and freely accessible to people of all social classes • Planning of interconnected park clusters or complete park systems

2.1.3 Development of urban parks in China

2.1.3.1 Urban parks before the mid-20th century

Since the first Opium War (also known as the Anglo-Chinese War) in 1840, with Western invasion and colonization of China, the nation has inflicted great shame and profound damage. Concurrently, this period precipitated a considerable influence of Western culture on the construction and development of urban spaces within the country. Notably, urban parks emerged within the concessions of major cities, including Macau, Shanghai, Guangzhou, and Tianjin. Initiated in 1861 and opened in 1865, Macau's San Francisco Garden is recognized as the earliest urban park in China developed by Western colonialists. It is among the first batch of park cultural heritages in modern Chinese cities, with its original form largely preserved (Li et al. 2022). It exhibits the characteristics of southern European urban gardens and embodies an artistic style of garden architecture that merges Eastern and Western elements, featuring green spaces, recreational facilities, and regular garden activities (***Figure 2.5***). Another notable example is the opening of the Public Garden (today known as Huangpu Park) (***Appendix 3***) within the Shanghai Concession in 1868, designed in the English landscape garden style, which h includes hedges, woodlands, lawns, a gazebo, and a fountain (Shen 2002). However, this park was exclusively accessible to foreigners, a practice apparently at odds with the concurrent Western notion of a public park designed to be freely accessible to the general public.

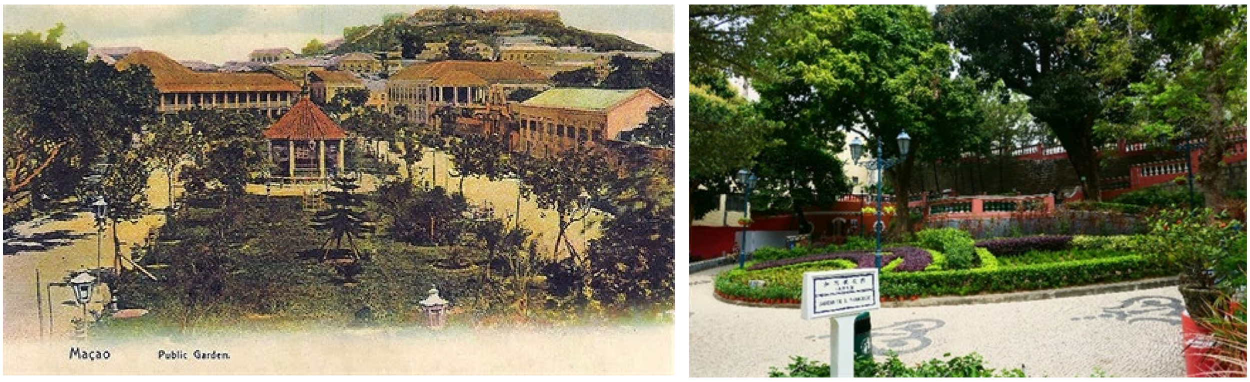

Figure 2.5: Macau's San Francisco Garden in 1890s and in 2021 (Source: Li et al. (2022)).

Following the Xinhai Revolution (1911), which led to the downfall of the Qing dynasty, a significant shift occurred in the utilization of Beijing's imperial gardens, as they were gradually transformed into urban parks open to the broader public. In 1914 and 1915, the Altar of Land and Grain (formerly known as Central Park, now Zhongshan Park)[9] (***Appendix 4***) and Xiannong Altar[10], domains previously dedicated to imperial rituals, were opened to the populace. This marked the commencement of a broader trend, as a succession of other significant imperial sites were progressively accessible to the public. These included the Temple of Heaven, the Imperial Ancestral Temple (today's Beijing Working People's Cultural Palace), the Altar of Earth (today's Ditan Park), the Summer Palace, and what are today known as Beihai Park and Jingshan Park. This transformation of exclusive imperial gardens into publicly accessible parks signifies a notable advancement in societal progress.

In addition, in response to the public's burgeoning demand for urban public spaces, a series of autonomously created urban parks emerged across China. According to Zhu Junzhen (2012), Jiuquan Park in Gansu Province (***Figure 2.6***), which opened to the public in 1879, was the earliest park developed by the Chinese themselves. Financed through public funds and donations from officials, this park was situated in the suburbs and designed for recreation and leisure, regularly open to the public. It pursued the aesthetic of a traditional Chinese garden, characterized by a harmonious blend of natural and artificial elements. Moreover, the beginning of 20th century saw the opening of several other pioneering parks in China, developed independently by the Chinese, such as Shangbu Park (today's Zhongshan Park) in Jinan, Cangxi Park (today's Longsha Park) in Qiqihar, Hebei Park (today's Zhongshan Park) in Tianjin, and Public Garden (today's Xijin Park)

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[9] The People's Government of Beijing Municipality website (https://baike.baidu.com/reference/6201625/533aYdO6cr3_z3kATP2LmKn5YCuXYN74v7LVWuNzzqIP0XOpX5nyFIo36d028PApEwTd_ptsL8QQmP-vVFQZraFNbu81QLUilWm7UTPAyb7u_99em9hDpolBXbNPw6yt). Accessed June 2023.

[10] The People's Government of Beijing Municipality website (https://baike.baidu.com/reference/2109574/533aYdO6cr3_z3kATP2LmPTxOn6VPt3-v7KFW7BzzqIP0XOpX5nyFIo36d028PApEwTd_ptsL8QQmP-vVFQPquhTK74qGP892jKtDjLdgeCi_sYzmtNFo4tcHK8XhfDxt0X_vSGI2LjdtTn9zCDAug). Accessed June 2023.

in Wuxi, among others. These early self-built parks laid the foundation for the development of modern urban park construction in China. Subsequent to the Xinhai Revolution (1911), a series of representative urban parks began to appear successively in various large and medium-sized cities Chinese cities. Notable examples include Central Park (today's People's Park) in Guangzhou, Yuexiu Park in Guangzhou, Xuanwu Lake Park in Nanjing, and Shouyi Park in Wuhan. Influenced by the wave of learning from the West during the period, most modern parks showcased a blend of Chinese and Western design styles. The creation of these parks signified substantial progress in the evolution of urban parks in China. However, due to the ensuing social disturbances, especially wars, the development of urban parks was markedly stalled. Some parks sustained damage, and those that remained were often neglected, characterized by barren landscapes and deteriorated facilities. By the time of liberation in 1949, there existed merely 112 urban parks in China, covering a total area of 2961.45 ha (according to China Statistical Yearbook).

Figure 2.6: The present Jiuquan Park in Gansu Province with a willow originally planted there (Source: Sohu website[11] and Meipian website[12], respectively).

In summary, the period from the mid-19th to mid-20th century represents a pivotal phase in the progression of urban parks globally. During this period, the development of urban parks in China was notably influenced by Western practices, embedded in a broader context of cultural exchange and social transformation. However, despite this convergence, the publicness, design style, and functional purposes of urban parks in China and the West maintained significant differences (***Table 2.3***), reflecting their unique cultural, social, political, and environmental contexts. Different from other Chinese urban parks that are open to the public, the parks within the concession areas of China usually exhibited restricted access, primarily catering to the colonial residents, a stark divergence from the concept of public parks in Western countries. In contrast, urban parks transformed from Chinese imperial gardens or constructed autonomously by the Chinese typically preserved their unique Chinese garden aesthetics, differentiating them from the design and layout

[11] Meipian website (https://www.meipian.cn/38fw749v). Accessed June 2023.
[12] Meipian website (https://www.meipian.cn/2cvndqo5). Accessed June 2023.

of Western urban parks and those within China’s concession areas. Both Chinese and Western urban parks served basic functions of providing green spaces for recreation and leisure, and fostering social interaction, albeit with variations in preferred activities. However, a key distinction lies in the emphasis placed by the West on urban parks as essential elements for enhancing public health and sanitation, conceived as “green oases” to mitigate the negative impacts of industrial urban sprawl. Additionally, Western urban parks often fulfilled educational purposes, integrating botanical gardens, zoos, or museums, an aspect less emphasized in China during that period, where urban parks were more concerned with displaying traditional culture alongside modern achievements.

Table 2.3: Comparison of Chinese and Western urban parks from the mid-19th to mid-20th century (Source: Author).

<table>
<tr><th colspan="2">Category</th><th>Publicness</th><th>Design style</th><th>Functional purposes</th></tr>
<tr><td rowspan="3">Chinese</td><td>parks in the concession areas</td><td>Restricted access</td><td>Diverse Western garden style</td><td rowspan="3">☑ Recreation and leisure
☑ Social interaction
☒ Public health and sanitation
☒ Educational roles</td></tr>
<tr><td>parks transformed from imperial gardens</td><td>Public access</td><td>Traditional Chinese garden style</td></tr>
<tr><td>parks constructed autonomously</td><td>Public access</td><td>Mixed Chinese and Western style</td></tr>
<tr><td colspan="2">Western public parks</td><td>Public access</td><td>Diverse Western garden style</td><td>☑ Recreation and leisure
☑ Social interaction
☑ Public health and sanitation
☑ Educational roles</td></tr>
</table>

2.1.3.2 Urban parks after the mid-20th century

During the initial phase of urban development after the founding of the People’s Republic of China (PRC) in 1949, park construction gradually received national attention and support (Pi 2013). Influenced by revolutionary cultural ideas as well as park design theory and experience from the former Soviet Union, urban parks were designed with a focus on functional zoning and land use balance, featuring a cultural rest park model. The parks emphasized group activities and served as platforms for political propaganda and cultural education (Yao 2013). Following this design concept and tool, some new parks were created in the 1950s, such as Yuexiu Park in Guangzhou, Taoranting Park in Beijing, and Xiaoyaojin Park in Hefei, among others. Taking Beijing Taoranting Park as a specific example, the park encompasses five functional zones, as depicted in ***Figure 2.7***. Also noteworthy, the introduction of the UGS system theory from the former Soviet Union during this period expanded the vision and scale of individual gardens and parks, incorporating them into urban landscapes.

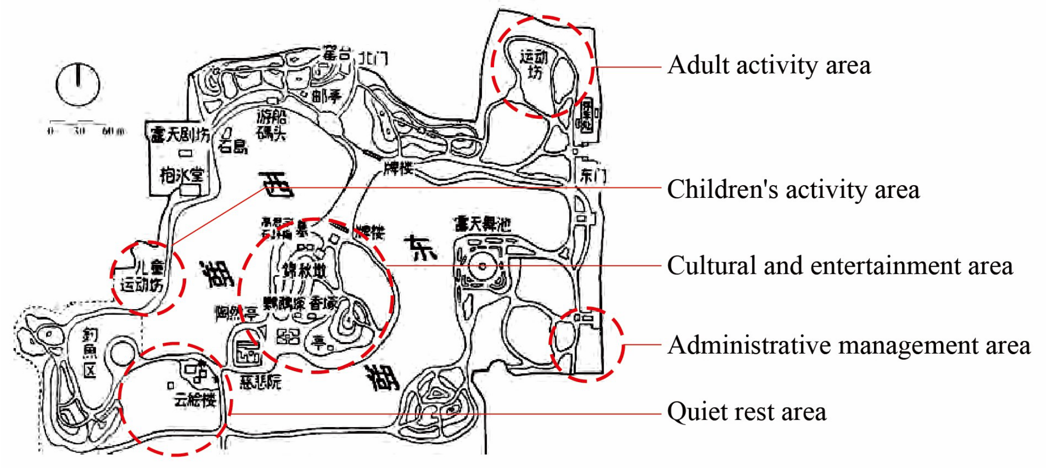

Figure 2.7: Beijing Taoranting Park structure in the 1950s (Source: Han (1958)).

In 1958, aimed at improving China's environmental appearance, the national landscaping and gardening movement[13] was initiated, markedly boosting the construction of urban parks. In accordance with the guiding principle of "combining gardening with production"[14], parks prioritized agricultural production functions. The emphasis on utilitarian plant species, such as crops, vegetables, fruits, and herbs, led to a neglect of the aesthetic and recreational value of urban parks (Luan et al. 2004). For instance, Zhongshan Park in Beijing (***Figure 2.8***) implemented a layout that included planting various fruit trees and medicinal plants, as well as utilizing water bodies for fish farming.

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[13] The national landscaping and gardening movement was first explicitly mentioned in a central document on December 10, 1958, in the *Resolution on Several Issues Concerning People's Communes* adopted by the Sixth Plenary Session of the Eighth Central Committee of the Communist Party of China.

[14] The guiding principle of "Combining gardening with production" was initially introduced at the First National Urban Greening Conference convened by the Ministry of Construction in February 1958.

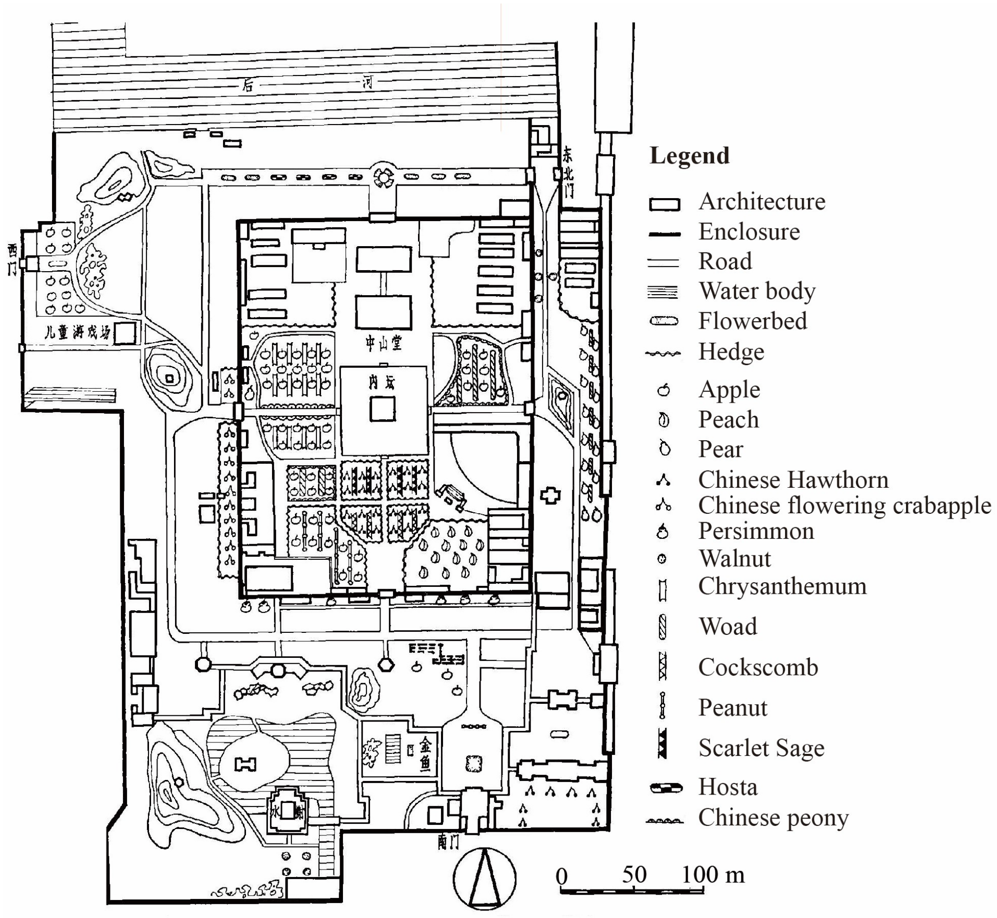

Figure 2.8: Beijing Zhongshan Park in the 1970s (Source: Beijing Zhongshan Park Management Office Horticulture Class (1974)).

It was not until 1978, following China's reform and opening up, that urban park construction has achieved a correspondingly steady development alongside social and economic progress. The parks emphasized design approaches that blend tradition and modernity. This enhancement of cultural and aesthetic features is exemplified by Fangta Garden in Shanghai (***Figure 2.9***), designed by Jizhong Feng and opened in 1982. It combines elements of Chinese classical gardens with modern design approaches, incorporating features such as a square pagoda, large lawns, pavilions, and bamboo groves, thereby achieving a balance between traditional culture and modern functionality.

Figure 2.9: Fangta Garden in Shanghai (Source: Youth Landscape Architecture website[15]).

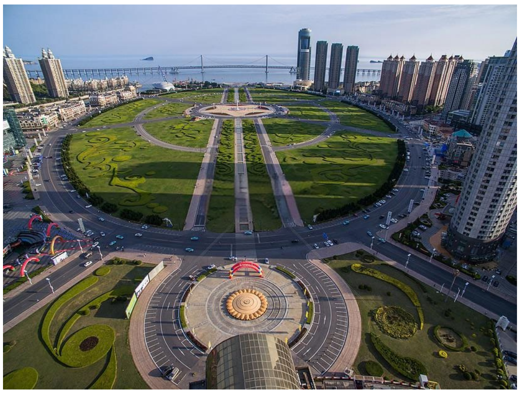

Figure 2.10: Xinghai Square in Dalian (Source: Shetu website[16]).

In 1992, the "Landscape Garden City"[17] model was proposed to beautify the urban landscape, enhance the city's image, and improve the investment environment. This landscape design is characterized by its spectacular and demonstrative style, with urban parks featuring large squares, monumental sculptures, and decorative spiral flowerbeds. A notable example is Xinghai Square in Dalian (***Figure 2.10***), the largest square in Asia, covering 1.76 km^2, which is approximately four times the size of Tiananmen Square. While this approach enhances the cityscape, it also faces issues of disproportionate scales and monotonous forms.

The tender, auction and listing policy in land, implemented in 2004, significantly promoted the development of the real estate market. Driven by market demands, urban park design increasingly diversified, incorporating elements such as brownfield landscapes and wetland parks. Modernism, Postmodernism, Land Art, and various other design ideologies surged in. However, the uncritical adopting of various foreign designs was observed, resulting in a mixed quality in landscape design.

In 2012, the construction of an "ecological civilization"[18] was highlighted as a national strategic decision. The focus of urban park construction gradually shifted towards environmental sustainability, leading to the implementation of sponge city practices. Emphasis was also placed on humanistic orientation, grounded in cultural preservation and experiential functions. Subsequently, park development has increasingly emphasized the planning of comprehensive park systems, with a particular focus on equitable distribution. To improve the service radius coverage

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[15] Youth Landscape Architecture website (http://www.youthla.org/2011/01/new-understanding-to-old-cases-fangta-garde-shanghai/). Accessed July 2023.

[16] Shetu website (https://699pic.com/tupian-500686687.html). Accessed July 2023.

[17] The Ministry of Construction of the PRC introduced the concept of "Landscape Garden City" in 1992 and later formulated the Implementation Plan for Establishing National Garden Cities and National Garden City Standards in 2000 (https://www.mohurd.gov.cn/gongkai/zhengce/zhengcefilelib/200008/20000825_156922.html). Accessed September 2023.

[18] At the 18th National Congress of the Communist Party of China in November 2012, the construction of an "ecological civilization" was outlined in the report（https://www.gov.cn/ldhd/2012-11/17/content_2268826_5.htm) delivered by President Hu Jintao, and incorporated into the Party Constitution of the Communist Party of China (https://www.gov.cn/jrzg/2012-11/18/content_2269219.htm). Accessed July 2023.

of parks, the principle of "seeing greenery within 300 m and a park within 500 m"[19] based on urban residents' travel patterns has been advocated.

Table 2.4: Primary phases of urban park development in China since the mid-20th century (Source: Adapted from Zhao et al. (2015)).

Time	Landmark	Focus
1949	Founding of new China (PRC)	Cultural rest park model; UGS system
1958	National landscaping and gardening movement	Combining gardening with production
1978	China's reform and opening up	Combining tradition and modernity
1992	Landscape Garden City	Spectacular and demonstrative landscapes
2004	The tender, auction and listing policy in land	Diversified landscapes driven by the real estate market
2012	Ecological civilization	Environmental sustainability; Humanistic orientation; Park system

In summary, urban parks in China have undergone complex developmental phases driven by significant national policies, leading to substantial transformations in their design concepts, functional characteristics, and thematic types (***Table 2.4***). Moreover, urban parks have experienced a notable growth in both quantity and area over the past 70 years (***Figure 2.11***). As China's society, economy, and urbanization advance, urban parks continue to adapt and diversify, reinforcing their role as integral elements of green infrastructure and markedly improving the urban living environment.

[19] Government of the People's Republic of China website (https://www.gov.cn/gongbao/content/2013/content_2361586.htm). Accessed July 2023.

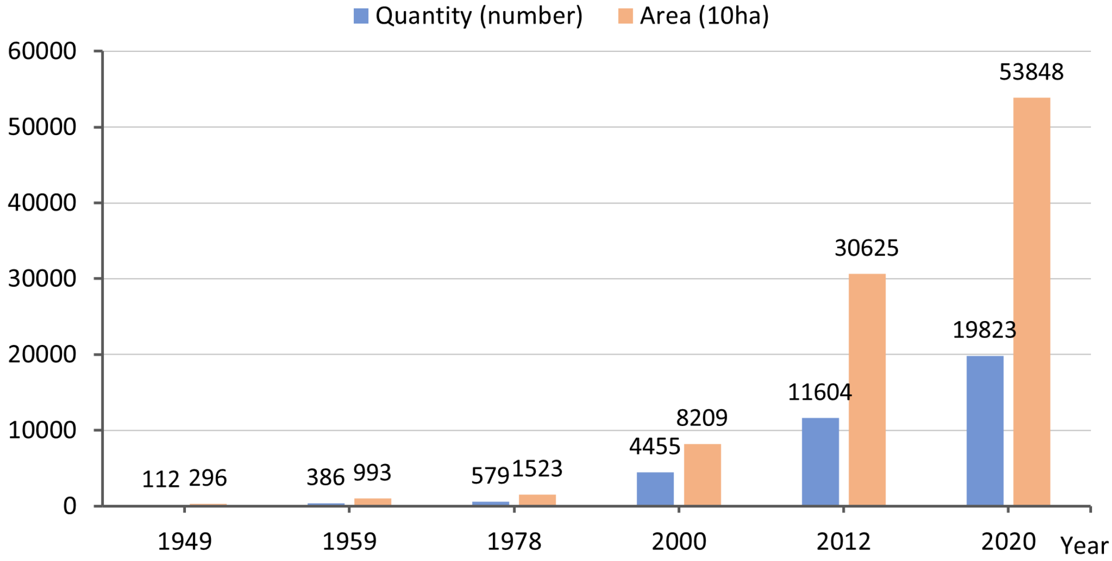

Figure 2.11: Total quantity and area of urban parks in China by year (Source: China Statistical Yearbook).

2.2 Distributional equity assessment in UPPs

This section aims to explore the developmental process and characteristics of distributional equity assessment in UPPs. It first contextualizes distributional equity within a multidimensional equity framework that also addresses procedural and contextual equity, thereby providing a holistic view of equity concerns. The subsequent analysis focuses on the advances in the assessment of distributional equity, categorized into four main modes by considering the context, content and characteristics across different developmental stages. It further investigates the features in the development of distributional equity from three distinct analytical perspectives. Through a systematic and comprehensive examination, this research can provide valuable insights into effective equity-oriented governance strategies for urban parks.

2.2.1 Multidimensional equity framework

In relation to the allocation of public facilities and se previous theoretical and empirical discourse on equity assessment typically lies on three dimensions: distributional equity, procedural equity, and contextual equity. These fields together are used to examine, evaluate, and plan for the impacts on equity changes in resource distribution. Drawing on Melanie McDermott's (2013) idea, they answer the question: "What counts as a matter of equity?".

(1) Distributional equity

Distributional equity focusses on whether the outcomes of resource allocation are equitable. The outcome analysis concerns with the allocation consequences of public parks among socio-spatial areas (e.g. communities of place) or socioeconomic groups (e.g. the elderly). It usually demands equal distribution of benefits from parks, which can be assessed through quantitative metrics, such as size, proximity, and quality, or more integrative indicators such as accessibility. Findings derived from existing studies have exhibited significant variability regarding both the direction and magnitude of these associations (Hughey et al. 2016). Multiple researchers have revealed deliberate discrimination in the distribution of public parks against vulnerable areas and disadvantaged groups. The National Recreation and Park Association (2011) conducted an extensive review and found consistent evidence of inequity in park provision in the United States. Wolch et al. (2014) examined the literature on green spaces and similarly revealed that low-income communities of color experience lower park services compared to white and affluent groups. However, an alternative perspective demonstrates that there are no systematic disparities, but rather even spread of inequities across the population. Mladenka and Hill (1977) indicated no particular discrimination against low-income neighborhoods in the distribution of public parks. Mladenka (1989) conducted research in Chicago and concluded that the distribution pattern of park services was not primarily determined by race, although there was a potential for social class to serve as a determinant. Additionally, certain scholars have pointed out that the distribution of public parks even tends to favor marginalized groups. Macintyre's (2007) review exhibited instances where low-income communities of color enjoy better access to health-promoting facilities, including parks, than other demographic groups. Xiao's (2017) empirical study on urban park access in Shanghai, China, discovered that vulnerable groups are in fact favored over more affluent citizens. In general, the empirical outcomes regarding equity patterns of public parks are multifaceted, exhibiting variations among various content of park values examined, diverse target groups of equity investigated, and different urban contexts studied.

(2) Procedural equity

Procedural equity is concerned with whether the processes of resource allocation is equitable. The process analysis highlights public participation in decision-making rules and implementation procedures for allocating public parks. It requires recognition of all people and affirmative efforts to ensure their inclusion, representation, and participation in decision-making (Hillier 1998, Schlosberg 2007). Practices of procedural equity vary, ranging from minimal guarantees of equal basic rights in decision-making processes to affirmative action favoring marginalized groups concerning access to public parks, such as low-income communities and elderly persons. European Commission's Green Infrastructure Strategy (European Commission 2013) demonstrates a growing policy interest in involving local stakeholders in spatial planning and decision-making processes to promote GI solutions in alignment with the principles of environmental justice. Raymond (2016) uses a digital tool, public participation GIS (PPGIS), to spatially identify and assess multiple elements of environmental justice in urban blue space based on individual preferences and experiences, which involves citizen feedback in urban blue space design and management. Cities in Northern European present various models, such as Malmo's Cooperation model and the Baltic Urban Lab to facilitate participation and citizen involvement in various urban regeneration actions, including the development of UGSs (Rutt et al. 2016). Overall, there are various ways to focus on inclusiveness and fairness in the procedural process. The specific effectiveness of inclusion and participation is influenced by multiple aspects, such as the persons invited to participate in the system, the means and mechanism of participation, the terms and extent engaged in decision-making.

(3) Contextual equity

Contextual equity focuses on whether the conditions of resource allocation is equitable. The condition analysis emphasizes the causal origins underlying the distribution of public parks. It acknowledges the presence of uneven capabilities among not only individuals but also groups, such as communities of place and elderly persons. The recognized identities, shaped by current societal norms and dominant sociopolitical narratives (Rutt et al. 2016), allow diverse social groups to collectively share respective pre-existing strengths and weaknesses. The initial social structure and institutional context have been extensively investigated to deeply explain inequitable group capabilities that enable or limit their capacity to benefit from park distributions. Mladenka (1980) argues that past decisions, population shifts, and black demands and protests are responsible for the distributional pattern of parks in Chicago. Boone (2009) attributed the social and institutional mechanisms that created separate black spaces historically underserved with parks in Baltimore, USA, to various factors including segregation ordinances, racial covenants, improvement associations, the Home Owners Loan Corporation, and the Parks and Recreation Board. Zhou (2013) identified four distinct dynamic forces that contribute to the formation of social spatial differentiation in parks in Guangzhou, China, including historical inertia and accumulation during urban development, selective renewal and filtration of the urban fabric, urban-rural dualization amid urban expansion, and the differentiation in citizens' consumption demands and abilities. Byrne & Wolch (2009) draw upon paradigms of park use and accessibility from environmental justice, cultural landscape, and political ecology perspectives to shift our attention away from park users and towards a more critical appreciation of the historical, socio-ecological, and political-economic processes that operate through and, in turn, shape park spaces and park-going behaviors. In short, existing studies have identified multiple factors and forces related to social relations and institutions that contribute to disparities in the allocation of public parks among various marginalized areas and people. A place-specific analysis of socio-political context and corresponding historical dynamics is considered necessary to illuminate the formation of distribution patterns.

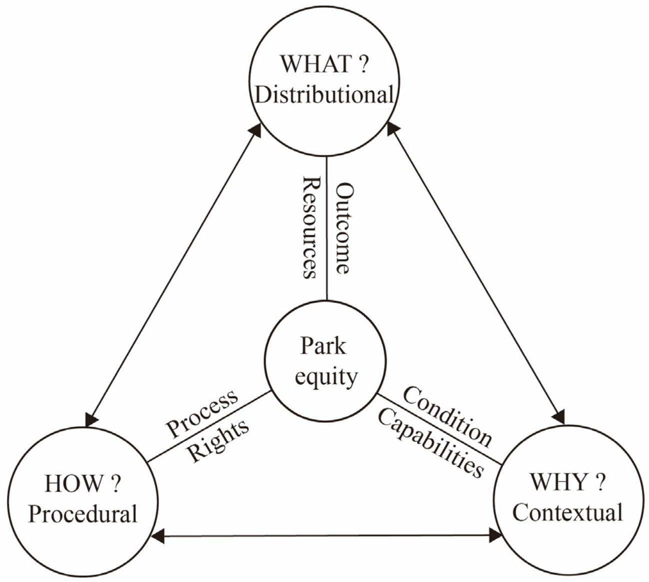

Figure 2.12: The multidimensional equity framework for urban parks (Source: Author).

Distributional equity serves as an initial framework for understanding who gets what. Procedural equity is fundamental for understanding how to allocate. Contextual equity is necessary to comprehend what the cause is. The dimensions of distributional, procedural, and contextual inequity are inherently interconnected (***Figure 2.12***). Contextual and procedural changes were expected to improve distributional outcomes (McDermott et al. 2013). Justice demands a fair distribution that is achieved in a just manner (Boone et al. 2009). Nonetheless, the interplay among distributional, procedural, and contextual equity is intricate, not always consistent. In a society inherently characterized by substantial inequity, adhering to a fair process may not necessarily yield a better equitable outcome.

2.2.2 Advances in distributional equity assessment

The public park movement laid the groundwork for the modern understanding that parks are not mere luxuries and amenities but critical urban infrastructure for the well-being of urban residents. The movement sought to democratize access to green spaces, characterized by the establishment of public parks in urban areas. Yet, despite the noble goal of creating public spaces is achieved, the early development of public parks often reflected and perpetuated the societal inequities of their times. The design and allocation of these parks primarily catered to the leisure preferences of privileged groups, with limited consideration for the broader public's needs. An illustrative example is the development of large bucolic landscape parks like Central Park in New York, which were significantly shaped by the desires of the male elite (Cranz 1982). This situation underscored the complex interplay between social hierarchies and the distribution of public parks. Nonetheless, these historical patterns of systematic inequity in park development have been constantly recognized and challenged.

According to previous research (Jiang et al. 2011, Zhou 2020), the development of distributional equity in UPPs is characterized by stages that align with the evolving social environment. Drawing on the developmental characteristics of societal contexts and corresponding public values advocated, this study argues that the distributional equity assessment in UPPs has undergone four main modes: territorial equality, locational fairness, group justice, and social equity (***Table 2.5***). They demonstrate cognitive distinctions in assessing the equity of park distribution and differ significantly in planning objectives, equity principles, as well as assessment approaches. The advances are closely linked to the development of urbanization and the construction of urban parks.

Table 2.5: Conceptual comparison of distributional equity models for UPPs (Source: Author).

Societal context & Public value	Distributional equity model	Cognitive focus	Planning objective	Equity principle
• Traditional public administration • *Efficiency* • City beautiful movement	Territorial equality	Equal share weight in different territories	Spatial guarantee	Welfare-based
• New public management • *Effectiveness* • New urbanism movement	Locational fairness	Fair opportunity of homogeneous persons	Spatial balance	Egalitarianism-based
• Civil rights movement • *Justice* • Environmental justice movement	Group justice	Just availability for disadvantaged groups	Socio-spatial matching	Need-based
• New public service • *Democracy* • Sustainable urban development	Social equity	Equitable benefit to groups of individuals	Socio-spatial satisfaction	Demand-based

2.2.2.1 Territorial equality

As a response to the challenges of industrialization and urbanization, traditional public administration was predominant in the early to mid-20th century. It placed a high trust in government as an agent for the good of all while prioritizing efficiency in government operations (Bryson et al. 2014). Moreover, the emergence and expansion of the welfare concept bolstered calls for societal values centered on equality (Briggs 1961). Emerging in the late 19th to early 20th centuries as part of the progressive social reform movement, the city beautiful movement aimed to improve urban environments and the quality of life for residents within burgeoning cityscapes (Wilson 1989). It integrated beautification and monumental grandeur into urban planning practices to promote social harmony and civic pride, which led to the creation of grand boulevards and park systems that were both functional and aesthetic. It had a lasting impact on contemporary urban planning worldwide, influencing the development of public spaces and urban aesthetic standards. Furthermore, the playground movement emerged as a pivotal component of the progressive era, prompting city officials to address park distributional issues (Boone et al. 2009). This shift moved the focus from merely designing parks as aesthetic or leisure spaces that catered to the interests of influential groups to also serving previously neglected demographics, including women, adolescents, children, and the working class (Young 1995). These efforts significantly contributed to the democratization of urban parks, providing amenities that supported a wide range of activities and were accessible to diverse social classes (Mattson 2010).

In light of this context, the concept of territorial equality is embodied in park planning and assessment. It implies equal share weight in different territories, and the planning objective is to achieve spatial guarantee of park resources. Territorial equality follows a welfare-based equity principle, whereby individual utility contributes to aggregate welfare (Konow 2003). Emphasis is placed on the efficient delivery of parks as public facilities, thereby enhancing social welfare. But the interpretation of equality from a territory-based perspective is crude and thus fails to ensure equal provision for everyone.

The notion of territorial equality centers firstly on guaranteeing the presence of a bottom line of park resources in the urban space. Utilizing spatial statistics and analysis methods, it further strives to assess the equality in resource density (e.g., per capita park area) among large-scale spatial units. For example, at the end of the 19th century, Tokyo, Japan, had set a per capita park area of 4.6 m^2 as the target for public park development (Xu 2003).

Territorial equality, based on the equity principle of welfare, guarantees an efficient and equal provision of park resources across various cities or districts. Nonetheless, equality assessment relies on a territorial scale, without considering the spatial location of parks, thereby neglecting the actual service effects associated with park distribution. And the allocation of park resources without due consideration for people’s basic needs can lead to the isolation of residents from parks.

2.2.2.2 Locational fairness

Emerging response to the shortcomings of large and centralized government agencies, new public management gradually became the dominant approach to public administration during the 1980s and 1990s. It was rooted in the belief in the efficacy and efficiency of markets and economic rationality (Bryson et al. 2014). Correspondingly, urban planning at the time emphasized service effectiveness and initiated the consideration of spatial location for public service delivery (Rich 1979). The movement now known as the new urbanism began to gain prominence in the 1970s and 1980s, as an important alternative to the conventional low-density, automobile-centric land development prevalent (Ellis 2002). It advocated for environmentally friendly and human-scaled practices through the development of walkable neighborhoods. A key aspect of this approach was the enhancement of pedestrian access to essential public amenities, notably urban parks (Ryan et al. 1995). In new urbanist designs, parks were often strategically placed to be accessible within a short walking distance from homes across diverse neighborhoods, thus facilitating access for all residents. The development of GIS enhanced urban planning through its capabilities in database management, visualization, spatial analysis, and spatial modeling (Han et al. 1989, Levine et al. 1989, Yeh 1999).

Under these conditions, locational fairness emerges as the primary equity criterion in park planning and assessment. It indicates fair opportunity of homogeneous persons, thus achieving spatial balance between park and population distribution. Locational fairness adheres to an egalitarianism-based equity principle, advocating for equal shares of resources for everyone. However, it is often physically unfeasible for parks to be situated equidistant from every location. Equal distance thus usually be substituted by threshold standards, which inherently implies the persistence of disparities in access to the parks for various locations. And the focus on equality primarily centers on the inputs of park resources. But equal allocation of park resources does not necessarily ensure equal park service outputs. Furthermore, it is a location-based assessment perspective that treats all residents as homogeneous persons with standardized need. Even equal services are unlikely to yield equal benefits as the actual needs for recreation opportunities vary among different social groups.

The conception of locational fairness highlights the assurance of basic proximity and accessibility of park resources to all locations, or rather to everyone. Through employing spatial statistics and analysis methods, it measures whether the threshold standards for parks in terms of place opportunity (e.g., proximity/a combination of proximity and quantitative density metrics) are equally met among small-scale spatial units. For instance, the European Environment Agency (EEA) advocates for people to have access to green spaces within a 15-min walking distance, approximately 900-1000 m (Stanners et al. 1995). In the USA, the National Recreation and Park Association (NRPA) proposed standards that integrated a maximum distance standard (one-half mile service radius) with an acres per population standard (one acre per 800 persons), which were widely used in park allocation in the 1900’s (Gold 1973).

Locational fairness, grounded in the equity principle of egalitarianism, ensures equal access to threshold-standard park resources across communities or neighborhoods. But upon reaching the minimum threshold for distance and density standards in the provision of park resources to every location, systematic disparities in the park distribution may persist among different locations. Moreover, as park metrics primarily concern the size and location recommendations, there may be deliberate discrimination against marginalized groups in the provision of park service quality. Besides, locational fairness is concerned with the standardized allocation of park resources to uniform groups, regardless of the disparities among different social groups. Therefore, equal treatment sustains the existing inequalities within the social structure and corresponding socio-spatial differentiation.

2.2.2.3 Group justice

In reaction to increased social differentiation, the civil rights movement emerged as a critical force by the mid-20th century, challenging racial segregation and advocating for equal rights for African Americans (Morris 1984). A significant achievement during this era was the Civil Rights Act of 1964 enacted to dismantle institutionalized racism, which prohibited discrimination in access to public facilities. Urban planners were called upon to integrate considerations of justice across all persons into planning practices (American Institute of Certified Planners 1991, Metzger 1996). Following this, the late 20th century introduced the environmental justice movement, highlighting how environmental burdens were disproportionately distributed among populations, especially affecting ethnic minority and low-income communities (Bullard 2018, Mohai et al. 2009). Subsequently, scholar and activism were increasingly interested in environmental amenities, with a particular focus on unjust distribution of UGSs (Boone et al. 2009, Wolch et al. 2005). This movement illuminated the systemic disparities in access to urban parks, thereby catalyzing efforts to ensure that the benefits of such spaces are available to marginalized groups. Under neoliberal urban regimes, environmental nonprofit organizations have assumed a significant role in addressing disparities in park provision by strategically targeting underserved communities (Rigolon 2019).

Consequently, the perspective of the equity concept began to shift towards group justice. It refers to just availability for disadvantaged groups, which pursues the socio-spatial matching of park services with different social groups. Group justice adheres to a need-based equity principle, which holds the idea of redistributing resources in a compensatory manner for mitigating the inequity of social group distinctions. In the discourse on the delivery of park services, two general arguments regarding group justice can be observed. One viewpoint asserts that all social groups should have equal rights and opportunities to access equal public services. The other perspective takes it a step further, arguing that unequal should be treated unequally in park allocations. Need-based equity is a people-centered principle rather than previous place-centered ones, which can lead to more humanistic outcomes in park allocations. And the assessment is directed towards the equity in park service outputs, considering not only park quantity but also their service quality, particularly from the standpoint of marginalized and vulnerable groups. Moreover, it cares about compensating for the disparities in recreation involvement capabilities by addressing the actual needs for park services among socio-economically and socio-demographically disadvantaged groups. Therefore, public participation in decision-making and implementation procedures, with a particular emphasis on the inclusion of disadvantaged groups, assumes a crucial role. Notably, unequal treatment requires some defensible basis for the inequality (Lucy 1981).

The concept of group justice aims to ensure equal access to equal park services for spatially clustered disadvantaged groups. Through a socio-spatial survey and evaluation approach, it assesses the availability patterns of park services (e.g., a combination of proximity, and quantitative and qualitative density metrics) among various social groups. For example, numerous studies have documented deliberate discrimination in the availability of park services directed towards certain social groups, such as low-income people and ethnic minorities (Chen et al. 2020, Dai 2011, National Recreation and Park Association 2011, Sharifi et al. 2021, Wolch et al. 2014). However, the distribution pattern of park services and identified disadvantaged groups can vary depending on the urban context. Furthermore, public services are viewed as potentially redistributive instruments through which government attempts to compensate for the inequalities generated in the private sector (Harvey 2010). It strives to provide more of park services to those who exhibit more specific needs on the belief that a minimum threshold of adequacy of access to recreation opportunities (public and private) should be met (Krumholz et al. 1990, Lucy 1981). However, making the need concept operational necessitates the use of objective indexes to identify communities with higher needs for park services. One type of metrics, like median family income and mean housing price, probably indicate a recognition of constraints in access to alternative recreational opportunities, both public and private. The other type of metrics, like elderly population ratio and young population ratio, often signify a consideration for greater reliance on outdoor activities in parks.

The need-based equity principle of group justice attempts to reduce objective socio-spatial disparities in the supply of park services for the benefit of marginalized or vulnerable groups. Differential considerations in park service delivery primarily focus on socially disadvantaged groups, with a deficiency in the diverse consideration of individual uniqueness. As differences in the demand for park services become increasingly apparent, the standardized output of park services may give rise to issues such as low usage and negative attitudes of parks. Moreover, after meeting the basic need criteria for park services, the ongoing advance of the assessment of park distribution has brought forth an emphasis on diverse preferences of individuals.

2.2.2.4 Social equity

In light of the challenges posed by market and government failures, coupled with a growing concern with deepening inequality and "downsized" citizenship, the public administration approach of new public service has been developed since the early 21st century. It pursues public values beyond efficiency and effectiveness, placing a particular emphasis on democratic and constitutional values (Bryson et al. 2014). Government is required to respond to active citizenship and public service delivery pursues the notion of equity that meets citizens' shared interests (Bryson et al. 2014, Denhardt et al. 2001). In the face of challenges posed by climate change, urban sprawl, and socio-economic disparities, sustainable urban development has increasingly become a critical direction for global urban policies and practices (Liu et al. 2014, Tonne et al. 2021, Yigitcanlar et al. 2015). Urban renewal and governance have increased its focus on the importance of UGSs and their distributional equity. Moreover, the emergence of the “just green enough” approach advocates for the creation and maintenance of urban parks that balance environmental sustainability with social equity, avoiding the trap of green gentrification (Rigolon et al. 2020, Wolch et al. 2014). Thus, there’s an increasing emphasis on participatory planning (Fors et al. 2015, Loures et al. 2008), which involve local stakeholders in decision-making process as well as ongoing maintenance (European Commission 2013, Meerow et al. 2019).

In this phase, equity assessment of park distribution starts to focus on the concept of social equity. It implies equitable benefits to diverse groups of individuals, thereby reflecting citizens’ socio-spatial satisfaction regarding park services. Social equity follows a demand-based equity principle, asserting that differences should be treated differently by targeting quality of life. Demand-based equity is also a “people-centered” principle, differing from need-based principle by shifting emphasis from a focus on the needs of certain social groups to a greater inclusivity of varied individual demands. And it relies on individuals’ subjective preferences rather than being based on objective need criteria established by the public sector. So, it incorporates targeted responsiveness into the park service delivery rather than standardized outputs. Furthermore, the concept of demand for services implies that at least a reasonable minimum threshold of service quantity and quality should be fulfilled (Lucy 1981). Demand functions as a method to determine whether additional services should be offered in one location rather than another. Therefore, there must be a foundation for distinguishing between them.

The concept of social equity seeks to respond to the diverse preferences of individuals for park use. By employing a socio-spatial survey and evaluation approach, it assesses actual performance in providing adequate park services in terms of size, location, and quality (amenities and facilities, aesthetics, activities, safety, etc.) to citizens. It measures objective behaviors and patterns of residents in their daily utilization of parks on one hand and investigates citizens’ subjective attitudes and opinions regarding park services on the other hand. The feedback regarding low usage and negative attitudes provides the basis for refined adjustments in park planning. Rall et al. (2019) employed a digital tool, PPGIS, for obtaining socio-perceptual data at a fine scale to explore relationships between cultural ecosystem service values, perceptions and uses of green spaces in Berlin, thereby enhancing urban green infrastructure planning and assessment.

Social equity, rooted in a demand-based evaluation principle, expects to achieve distributional equity concerning park benefits by incorporating public interest and user response. Naturally, the responses in public service delivery are often complex and have consequences. Owing to financial constraints, it is unfeasible to fulfill all demands. Given the inherent objective conflict arising from diverse values, it is also impossible to accommodate the preferences of everyone. Furthermore, planners are frequently confronted with the decision of whether to weigh their own judgments of expertise and equity. In this case, if persuasive response is to be made other than randomly or arbitrary, overlapping consensus from diverse demands must be invoked. Ensuring and achieving overlapping consensus necessitates procedural equity in the process of park planning. Public participation, with a particular focus on ensuring opportunities for disadvantaged groups, assumes a crucial role. Moreover, it is worth noting that equity concepts are not isolated from each other. In the decision-making process, other equity principles, including welfare, egalitarianism, and need, may be reintroduced into the consideration of planning proposals.

2.2.3 Features in the development of distributional equity

2.2.3.1 Development characteristics of distributional equity models

In the assessment of UPP allocation and delivery, four primary models for distributional equity have been identified, each demonstrating significant distinctions in terms of planning objectives and equity principles. Territorial equality strives for spatial guarantee and aligns with the welfare-based principle. Locational fairness pursues spatial balance and adheres to the egalitarianism-based principle. Group justice seeks socio-spatial matching and follows the need-based principle. Social equity aspires to socio-spatial satisfaction and adheres to the demand-based principle (***Figure 2.13***).

In summary, there has been a discernible shift in the assessment subjects and measurement criteria associated with the level of urbanization, the degree of urban construction, and the corresponding mode of park development. During the early and accelerated phases of urbanization, within the context of large-scale underway construction of modern urban functions and spatial systems, urban parks exhibit an extensive development mode. Park resource allocation is approached from a "place-based" and "consequence-oriented" perspective. In the phase characterized by the fundamental completion and self-enhancement of urbanization in developed regions, the development of urban parks manifests a refined mode, emphasizing the micro-renewal and governance of urban space. Park service delivery is directed by a "people-based" and "rule-oriented" perspective.

However, the development of the concept of distributional equity in UPPs is not characterized by the mutual substitution of old and new ideas. Instead, it unfolds in conjunction with the support of urban construction development, gradually expanding in tandem with the progression of public value governance. Specifically, the aspirations for distributional equity at each stage typically built on the accomplishment of objectives of distributional equity from the preceding stage. The inadequacies in the cognition of distributional equity at each stage usually function as a prerequisite for deepening the conceptualization of distributional equity in the subsequent stage.

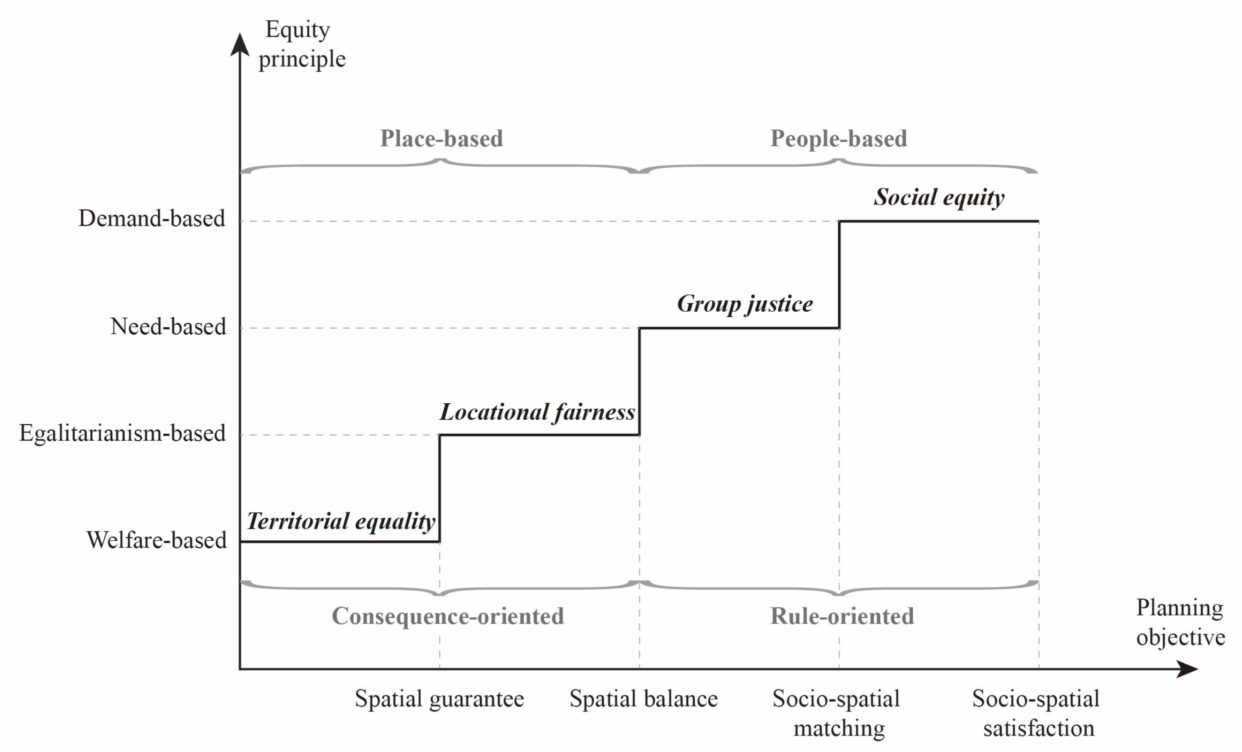

Figure 2.13: Developmental characteristics in equity models, planning objectives, and equity principles for park distribution (Source: Author).

2.2.3.2 Transformations in metrics between parks and residents

Constrained by urban development levels and cognition of distributional equity, the assessment of territorial equality and locational fairness is confined to a physical spatial framework and the top-down perspective of park resource provision. Based on quantified spatial relationships, this assessment focuses on the question: "Where and how many resources are provided?". The measurement of parks is predominantly grounded in attributes of size (and location), with service quality often being disregarded. Residents are often regarded as homogeneous persons, with a focus on population (and distribution), without considering social spatial differentiation and group distinctions. Through spatial statistics and analysis method, indicators such as resource density or place opportunity are employed to analyze the park distribution patterns. They lack a comprehensive analysis of park attributes, resident characteristics, and the interaction dynamics between parks and users.

In terms of group justice and social equity, the assessment of distributional equity is anchored in the context of social space and the bottom-up standpoint of park service supply. Premised on a broader and deeper intersection between parks and residents, this assessment explores the question of "Who receives what kind of services?". The measurement of parks integrates park attributes, such as size, location, and quality (amenities and facilities, aesthetics, activities, safety, etc.), with resident characteristics, including population, distribution, and capability (sociodemographic characteristics, socioeconomic status). In particular, social equity emphasizes individual preferences for parks, encompassing both behavioral patterns and attitudinal responses. A socio-spatial survey and evaluation method has been developed to thoroughly investigate the needs and demands of diverse groups. Indicators such as group availability and service performance are used to systematically measure the distributional equity (***Table 2.6***).

Table 2.6: Transformations in metrics between parks and residents of distributional equity models (Source: Author).

Distributional equity model	Metrics		Indicator	Method
	Park attributes	Resident characteristics		
Territorial equality	• Size	• Population	Resource density	Spatial statistics & analysis
Locational fairness	• Size • Location	• Population • Distribution	Place opportunity	
Group justice	• Size • Location • Quality (amenities and facilities, aesthetics, activities, safety, etc.)	• Population • Distribution • Capability (sociodemographic characteristics, socioeconomic status)	Group availability	Socio-spatial survey & evaluation
Social equity	• Size • Location • Quality (amenities and facilities, aesthetics, activities, safety, etc.)	• Population • Distribution • Capability (sociodemographic characteristics, socioeconomic status)	Service performance	
	• Preference (behavior, attitude)			

Overall, the measurement of park distribution has progressed incrementally, shifting from a primary emphasis on physical space to an exploration of the dynamic interplay between space and society. This transition involves a departure from a city space standpoint to an orientation focused on citizens, with the aim of seamlessly integrating objective distribution and subjective experiences. The associated metrics have transformed from highlighting the resource quantity and spatial location of parks to assessing the service quality and benefit output for residents. Accordingly, the distinctions are explicitly reflected in the evaluation methods and measurement indicators. Furthermore, leveraging big data for enhanced efficiency and accuracy in information collection, the spatial units for measuring distributional equity have shifted from cities and districts to finer geographical scales, such as communities and neighborhoods.

2.2.3.3 Relationships with contextual equity and procedural equity

In relation to the equity of public service delivery, previous theoretical and empirical discourse typically lies on three dimensions of the equity framework: distributional equity, procedural equity, and contextual equity. Procedural equity is crucial to the transparency and justice of how park allocation decisions are determined. Involving members of all parties, especially marginalized groups, in decision-making and implementation procedures ensures that their perspectives and voices are considered. Equity in park allocation depends not only on outcomes but also equally on the process a person is treated or expects to be treated (Low 2016). Contextual equity is essential not only to acknowledge individual disparities but also to recognize group disparities in capabilities. It addresses the characteristics and needs of different communities or social groups, though context itself may not be amenable to control through park planning. Considering the specific social conditions of disadvantaged groups ensures that the allocation of resources and opportunities is tailored to their circumstances. Drawing on the idea of McDermott et al. (2013), distributional equity, procedural equity, and contextual equity together answer the question: "What counts as a matter of equity?".

There is no doubt that, within the discourse on equity in UPP planning and assessment, distributional equity has remained a classical dimension of concern in the equity framework. However, the emphasis on distributional equity is often seen as potentially leading to a neglect of both procedural and contextual equity. Practical developments in park allocation have suggested that this is not always the case. The relationship between distributional equity and the other two dimensions of the equity framework depends on how distributional equity is understood and how its concepts are applied to planning proposals.

Table 2.7: Relationships of distributional equity models with contextual equity and procedural equity (Source: Author).

Distributional equity	Territorial equality	Locational fairness	Group justice	Social equity
Procedural equity	-	-	+	+
Contextual equity	-	-	+	+

Note: - denotes no relationship; + denotes a relationship.

Territorial equality and locational fairness implement one-size-fits-all solutions without considering the differentiation of social spaces and the stratification of social groups. Clearly, contextual equity and procedural equity are not necessary to achieve either of these narrowly defined types of distributional equity. In contrast, group justice and social equity require solutions tailored to specific needs of social groups or diverse demands of individuals. In this context, procedural equity is necessary to guarantee that the mechanisms governing park allocation are just and inclusive, while contextual equity ensures that distributional equity is achieved in a meaningful and targeted way. Compared to territorial equality and locational fairness, it can be argued that group justice and social equity represent more profound cognition of distributional equity, which closely intertwined with procedural equity and contextual equity (***Table 2.7***).

2.3 Accessibility measurement for assessing equity

This section aims to provide a comprehensive overview of how accessibility measurement contributes to equity assessment in the context of urban parks. It begins by examining the relationship between spatial accessibility and distributional equity and then offers insights into how spatial accessibility is interpreted. This examination is followed by a detailed review of primary accessibility measures for urban parks, highlighting both their theoretical underpinnings and practical applications. Additionally, a comparative analysis of these measures is conducted to evaluate their conceptual differentiation and effectiveness in articulating equity. Through this in-depth examination, this research can advance our understanding of how refined accessibility measurements can inform more equitable urban park planning.

2.3.1 Spatial accessibility and distributional equity

2.3.1.1 Relationship between accessibility and equity

It is widely acknowledged that accessibility characterizes the behavioral responses to spatial separation between supply and demand locations (Kwan et al. 2003). Based on this understanding of accessibility, there are several consensuses. **a)** It is contextualized within the context of relative space, considering the interconnectivity of locations rather than examining them in absolute space. **b)** Accessibility and isolation frequently emerge as relatively comparative concepts within empirical settings, serving to articulate the relational structure of spatial systems. **c)** Furthermore, accessibility values gain significance only when compared within a specific region; therefore, accessibility reflects the status of a location within a broader context. Through comparative analysis across various locations, accessibility serves as a powerful tool for scrutinizing variations in resource distribution and identifying potential discrimination. Consequently, the degree of equity can be assessed based on differences in accessibility to public facilities and services. In general, equity guides research by focusing on identifying and understanding disparities in the provision of public facilities and services, while accessibility analysis functioning as a practical tool to examine whether equity has been achieved. These intertwined concepts play a crucial role in evaluating the distribution patterns of public facilities and services.

Building on spatial accessibility as a foundational metric, the distributional equity of public parks can be assessed, and equity-driven adjustments can be integrated into park planning. This iterative cycle of analysis, assess, and planning, informed by equity considerations, fosters enhanced accessibility within the framework of equitable public park allocation (***Figure 2.14***).

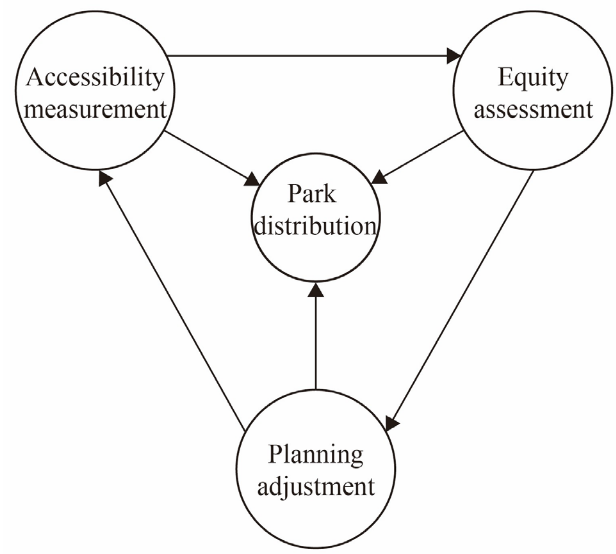

Figure 2.14: The connection for accessibility measurement, equity assessment, and planning intervention in urban park distribution (Source: Author).

Noteworthy, accessibility and equity are not always inherently intertwined, nor are they merely interconnected in a way based on spatial distribution. This distinction is illustrated, for instance, when examining two different perspectives on accessibility. Firstly, **accessibility from a geometric perspective**, grounded in location theory, strives to optimize the efficiency of distribution networks, thereby minimizing system costs (Nicholls 2001). This market determination of resource allocation relies on factors like willingness to pay for user fees, amount of taxes paid, or selecting the least costly system alternative (Talen 1998a). The efficiency-oriented analysis disregards considerations of distribution patterns of outcomes or who the beneficiaries are. This approach highlights the conflict between efficiency and equity and is therefore considered inappropriate for public service delivery. Secondly, **accessibility from a barrier-free perspective** seeks to address the inclusive design of facilities and services by removing of physical, sensory, or cognitive barriers to ensure equal access for all individuals, including those with disabilities (Fekete et al. 2012). This approach, also referred to as universal accessibility, focuses on the inherent qualities of public facilities and services in ensuring their availability to everyone. Such barrier-free analysis is not concerned with the spatial distribution of destinations or their physical separation from origins, but mainly addresses the social barriers faced by individuals with disabilities. In this light, the pursuit of equity requires a fundamentally different analytical framework. Consequently, the investigation of these accessibility approaches is not included within this study.

2.3.1.2 Spatial accessibility interpretations

The interpretation of spatial accessibility refers to how to represent geographic features, relationships, and attributes within a study's analytical framework. The way in which spatial accessibility is represented can significantly impact not only the possible research questions but also the interpretations and tools of spatial analysis. Joseph (1984) delineated accessibility into two distinct types: **potential accessibility and revealed accessibility**. Potential accessibility refers to the theoretical or prospective possibilities for access, highlighting the potential availability before it has been implemented. On the contrary, revealed accessibility pertains to the existing level of access that has been realized. It reflects the actual utilization of facilities and services. Kwan (2003) introduced a categorization of spatial accessibility into **place accessibility and individual accessibility**. Place accessibility pertains to how easily destinations can be accessed from locations or places. It relies on population data within a geographic zone to assess its aggregate accessibility. However, individual accessibility examines how easily an individual can access destinations. It employs activity-travel data at the individual level to measure the personalized accessibility within the constraints of their space-time environment. In addition, Chen et al. (2007) differentiated spatial accessibility into **objective accessibility and subjective accessibility**. Objective accessibility examines the physical attributes and spatial connections that affect the ease of reaching destinations. It incorporates measurable factors such as distance, transport options, travel time, and network connectivity. Conversely, subjective accessibility emphasizes an individual's psychological perceptions regarding travel to a destination. It recognizes that personal willingness and choices can impact access to certain destinations, even when the objective accessibility is conducive.

In general, there are diverse perspectives regarding the interpretation of spatial accessibility. The varied conceptualization and operationalization of spatial accessibility have given rise to diverse measurement methods. Within the context of urban parks, to facilitate operationalization, most studies employ measures that integrate potential accessibility, place accessibility, and objective accessibility. The efficacy of specific accessibility measures in reflecting the essence of equity models and guiding planning orientations depends on the particular interpretation of the accessibility concept and the precise specification of these measures.

2.3.2 Accessibility measures for urban parks

The choice of an accessibility measure is found to substantially influence the assessment of spatial equity, potentially resulting in different conclusions regarding the appropriateness of implementing certain policy interventions (Talen 1998b). There are five primary park accessibility measures: the container method, the buffer method, the distance-cost method, the cumulative-opportunity method, and the gravity-based method. Each of these methods exhibits distinct inherent characteristics. This section offers an in-depth analysis of the properties of various accessibility measures, critically evaluating their strengths and limitations at both theoretical and practical levels. Thus, by ascertaining the extent to which specific accessibility measure more accurately articulate equity, it becomes possible to advise on the most appropriate measure for assessing equity in the context of urban park accessibility.

(1) Container method

It is based on per capita opportunity share for zonal units and focuses on the equal allocation of park resources. This method evaluates citizens' accessibility to parks by examining the indicator of park area. Especially in Chinese cities, the indicator of per capita park area has been extensively employed to assess the provision of park resources and opportunities for accessing these facilities. A higher value of this indicator indicates better park accessibility for residents. The container method holds a significant position in facilitating horizontal and vertical comparisons of park disparities within urban zonal units of various hierarchies, including urban areas, districts, and subdistricts, due to its ease of calculation and interpretation. However, this method exhibits significant variations due to different approaches used to define zone boundaries or the size of the base area (Yu et al. 1999). Implicitly, it assumes that parks within the study units solely cater to the residents within those specific zones, and conversely, the residents can only access the parks located within their respective zonal units (Song et al. 2010). In reality, parks situated at the peripheries of zonal units not only serve the internal residents but also attract inhabitants from surrounding areas, particularly true for high-quality parks. Furthermore, the method assumes an equal benefit from park services among all residents within the region, disregarding the spatial distribution and ease of access to parks (Nicholls 2001). For instance, although a region may possess a multitude of parks, their concentration in a particular area with a lack of parks in other areas does not necessarily guarantee easy access for all residents.

(2) Buffer method

It examines the service scope covered by opportunities, considering the park service radius and spatial distribution. The traditional method creates a buffer around the park boundary with a radius of its service distance to indicate accessible areas or the population within reach. Additionally, by establishing multi-level service radius buffers for the park, it enables the identification of variations in accessibility levels within the service area (Liu et al. 2010). The buffer method is widely utilized in park service planning and accessibility evaluation due to its capacity to simply distinguish among areas with service provision, those lacking service, and those displaying service overabundance. However, despite considering the spatial distribution of parks, this method, like the container method, neglects spatial impedance factors such as geographical barriers (e.g., mountains, rivers) and transportation network. Moreover, it assumes homogeneously open boundaries for parks, disregarding the impact of their entry locations on the accessibility of users from different directions. These two factors collectively contribute to a tendency to overestimate park services and accessibility coverage (Nicholls 2001). Subsequently, the network analysis method emerges as an alternative that addresses the limitations of the traditional Euclidean radius method. It incorporates spatial impedance by measuring the coverage of the park based on transportation network within a certain travel distance or time. Additionally, the network analysis method considers travel distance or time from individual residences to each entry point of the park, thereby providing a more accurate reflection of citizens' actual access to parks. However, the buffer method ignores the influence of distance friction and assumes a uniform level of park service across all locations within its buffer, which does not accurately reflect reality. Another significant drawback is the considerable arbitrariness involved in determining the size of park buffers, especially in distinguishing between different types or levels of parks.

(3) Distance-cost method

It examines travel ease in overcoming spatial impedance, highlighting the importance of the nearest distance for citizens' daily access to parks. Travel distance or time may be used to measure spatial separation, the shorter the travel cost, the higher the level of accessibility. According to Ingram (1971), there are two types of accessibility measures: relative accessibility and integral accessibility. Relative accessibility assesses the minimum travel distance from one origin to the nearest destination. Inequity of access is inevitable, as some residents will always be closer to any given parks than others. This model strives to mitigate such inequity by selecting park locations that minimizes the longest travel distance from the origins to the nearest destination (Hodgart 1978). On a broader scale, integral accessibility measures the total or average travel distance from each origin to all destinations within the study area. This model seeks to improve accessibility by minimizing the overall travel distance. This method is considered the most intuitive approach to measuring accessibility, as it reflects residents' travel costs within the transportation network. Its ease of understanding and calculation makes it a commonly used method for studying the accessibility of public services (Hewko et al. 2002, Hodgart 1978, Yin et al. 2009). However, this method captures only the proximity between residents and parks, without accounting for variations in park attributes. It assumes that residents always choose the nearest or most convenient parks to visit, disregarding factors such as park area and quality, which may actually lead residents to prefer parks that are farther away (Yang et al. 2022).

(4) Cumulative-opportunity method

It investigates the number of accessible opportunities, considering the range of travel. Specifically, this method measures the quantity of accessible parks from a particular origin within a defined travel distance or time. All potential parks within this specified cutoff travel cost are assigned equal weight. The more opportunities available, the higher the level of accessibility. Through further grading the travel distance, the contour method can accumulate the number of parks accessible within various travel distances (Chen et al. 2007). As the travel distance increases, residents gain access to more parks, leading to a higher measure of accessibility. Moreover, all parks can be considered resident-accessible when the travel distance exceeds a certain threshold (Liu 2007). This method effectively illustrates the distribution of opportunity quantity in relation to spatial barriers or travel convenience. The accessibility metric can be compared not only across different residential locations within the same travel distance range but also for the same residential location across different travel distances. The commonly employed floating catchment area model (Luo 2004) is rooted in the concept of cumulative-opportunity method. A limitation of this method lies in the difficulty of selecting the cutoff travel distance, as the level of accessibility may be highly sensitive to this critical value (Ben-Akiva et al. 2021, Handy et al. 1997). This challenge is particularly evident when considering the accessibility of different types or levels of parks for a given residential location, making it difficult to determine appropriate thresholds. Furthermore, this method considers only the choices available to residents, neglecting the impact of the variations in travel distance to parks within a specified range.

(5) Gravity-based method

It is based on Newtonian physics of universal gravitation, focusing on potential of opportunities for interaction. This method is represented by the cumulative sum of the potentials exerted on a specific origin by all parks, capturing the supply of parks, the demand of residents, and travel distance. It is assumed that the attraction of a park to residents decreases as the distance and associated travel impedance from the origin increase (McGrail et al. 2009). The potential for citizens to access parks declines as spatial friction to reaching destinations increases but improves as the attractiveness between parks and residents strengthens. The larger the sum of the potentials, the better the accessibility. The distance-decay function, which weights opportunities by travel impedance (distance or time), plays a crucial role in the gravity-based model. In practice, power function, exponential function, and gaussian function are commonly employed to represent this decay in distance-based interactions (Liu et al. 2010), but these must be subjected to empirical travel behavior. This method provides a comprehensive and thorough analysis of accessibility, encompassing supply and demand factors as well as travel costs. Additionally, the relative importance of travel impedance in park choice is reflected by incorporating the weighted attractiveness of parks into the measure of accessibility. Several widely used models, such as potential model (Shen 1998), the 2SFCA model (Luo et al. 2003), and kernel density estimation (Spencer et al. 2007), derive from the gravity-based method. However, the gravity method has faced significant criticism, primarily regarding the challenges associated with the selection or empirical determination of the distance-decay function and corresponding decay coefficient specific to each study. Moreover, since the model is sensitive to parameter values on travel impedance, an overemphasis on the decay function results in heavily spatially smoothed outcomes (Luo et al. 2003), characterized by a highly concentric pattern of accessibility. Additionally, to measure the attractiveness of parks, it is necessary to choose and weight various characteristics of potential destinations. Nevertheless, some attractiveness variables are difficult to calibrate, rendering evaluations intrinsically subjective. Furthermore, in the typical scenario where the attraction measure is zonal, the measurement pertains to the accessibility that groups of individuals, hypothesized to be concentrated at zone centroids, have to opportunities clustered likewise (Pirie 1979). Thus, both zone sizes and the zonal configurations of residents directly affects the accuracy of capturing all individual travel perceptions within the same zone.

2.3.3 Comparison of accessibility measures

The specification of the accessibility measure significantly influences the extent to articulate equity (Neutens et al. 2010). Measures usually generate homogeneous accessibility values when they have limited ability to articulate locational differences across various dimensions of accessibility, thereby demonstrating reduced effectiveness in indicating a state of equity. A conceptual comparison of these measurement methods is conducted on four key components: spatial reference, measurement attribute, integration mechanism, and decision making (***Table 2.8***). They primarily facilitate the differentiation among various accessibility measures.

a) **Spatial reference** varies across different place types. The container method is restricted to zonal units and therefore cannot articulate accessibility heterogeneity across locations. The buffer method, the distance-cost method, and the cumulative-opportunity method all rely on a single type of reference location, either origins or destinations, for measuring accessibility. In contrast, the gravity-based method involves both origins and destinations, enabling it to effectively integrate the full scope of interactions between all supply and demand.

b) **Measurement attribute** encompasses three aspects: travel distance/time, park supply, and resident demand. In terms of travel, the container method does not account for differences in separation between supply and demand location, thus failing to represent actual accessibility. All other methods differentiate opportunities based on travel distance/time. Regarding park supply and resident demand, both the buffer method and the distance-cost method fail to take these two factors into account. The container method and the cumulative-opportunity method only consider a single measure of park supply. In contrast, the gravity-based method articulate differences in park supply through a composite measure of attractiveness, including measures of quantity, area, and quality. Only the container method and the gravity-based method recognize per capita differences by considering resident population.

c) **Integration mechanism** encompasses a range from the container method, focused on examining opportunity indicators, to the buffer method, which determines catchment areas. It also includes the distance-cost method for selecting the best opportunity, as well as the cumulative-opportunity method and the gravity-based method, both of which are designed to identifying the heterogeneity of opportunities.

d) **Decision making** focuses on whether the selection process is driven by meeting, optimizing, or satisficing strategy. The container method and the buffer method suggest that places should meet specific opportunity threshold, without regard to accessibility heterogeneity beyond that threshold. The distance-cost method strives to identify the optimal opportunity, but it allows limited flexibility for persons to adopt alternative decision rules in practical scenarios. The cumulative-opportunity method and the gravity-based method imply that the accessibility of a place increases with more alternatives to choose from, aligning more closely with the less restrictive assumption about the adoption of decision rules.

Table 2.8: Conceptual comparison of spatial accessibility measures for parks (Source: Author).

Accessibility measure	Spatial reference	Measurement attributes	Integration mechanism	Decision making
Container method	Zonal unit	• Travel not considered • Park area • Resident population	Examining per capita opportunity share for zonal units	Meeting opportunity indicator through availability threshold
Buffer method	Destination	• Travel distance/time • Park attributes not considered • Resident not considered	Determining service scope covered by opportunities	Meeting catchment areas through proximity threshold
Distance-cost method	Origin	• Travel distance/time • Park attributes not considered • Resident not considered	Selecting nearest opportunity in travel distance/time	Identifying optimal opportunity through proximity maximization
Cumulative-opportunity method	Origin	• Travel distance/time • Park quantity • Resident not considered	Summing opportunities within cut-off distance/time	Satisficing behavior through choice maximization
Gravity-based method	Origin & destination	• Travel distance/time • Park quantity & area & quality • Resident population	Scaling per capita opportunities based on attractiveness and proximity	Satisficing behavior through proximity, choice, and attractiveness maximization

Note: The origin denotes location of resident demand, and the destination denotes location of park supply.

In summary, from a conceptual point of view, it is evident that the gravity-based method appears to be a more effective measure. This is attributed to its ability to comprehensively articulate differences across various aspects, including the spatial distribution of parks and residents, travel impedance, park attractiveness, and resident population. This method involves the interaction between supply and demand, spanning spatial and social dimensions, as well as objective and subjective elements, all of which influence the opportunities available for residents to access destinations.

As a special case of the gravity-based method, the 2SFCA model incorporates the advantages of both cumulative-opportunity method and buffer method. This integration allows it to consider effective travel distances by imposing a distance threshold. Consequently, it has emerged as one of the most employed and developed accessibility measure (refer to Section 3.4.1).

3 MATERIALS AND METHODS

3.1 Case selection basis

The research proposes to deal with the basic global phenomenon of UPP development and equity. Given that landscape architecture is an applied science, a crucial component of the research methodology incorporates an empirical approach, exemplified by UPPs in Zhengzhou, China. The selection of Zhengzhou as a case study is based on three primary reasons, outlined as follows.

3.1.1 A significant role among Chinese cities

Zhengzhou is the capital of Henan Province (***Figure 3.1a***), one of the most populous provinces in China, containing around 100 million. It functions as the political, economic, technological, educational, and cultural centre of the province. Notably, it is renowned as one of China's eight ancient capitals and is proud to house the esteemed World Heritage Site - Historic Monuments of Dengfeng in "The Centre of Heaven and Earth". The region (112°42'-114°14'E, 34°16'-34°58'N) is geographically situated in Central-Eastern China and on the south bank of the lower reaches of the Yellow River. Encompassing an approximate area of 7446 km^2, it exhibits a topographical contrast with high elevation in the west and low elevation in the east. Leveraging its strategic central location, the city has effectively transformed into a prominent integrated transportation hub in central China. Its well-connected railway network and bustling international airport facilitate seamless connectivity to many domestic and major foreign cities. Since 2016, the city has been supported to become one of "National Central City", which is the highest level in the national urban system plan. This initiative has become a strong impetus to expedite the city's high-quality development. According to the ranking of cities' business attractiveness in China, Zhengzhou has been recognized as one of China's new first-tier cities since 2017. It shares this status with 15 other prominent cities, such as Chengdu, Chongqing, Hangzhou, and Wuhan, and ranks second only to top-tier cities of Shanghai, Beijing, Guangzhou, and Shenzhen in China.

3.1.2 A global representative of rapidly urbanizing regions

Zhengzhou has undergone rapid urbanization over the past few decades and was recognized by the Economist Intelligence Unit (EIU) in 2016 as one of the fastest-growing cities in China. By 2018, the region's population reached 10.14 million with a GDP of 1.01 trillion yuan[20], meeting the

[20] Zhengzhou Municipal Bureau of Statistics website (https://tjj.zhengzhou.gov.cn/tjgb/3109505.jhtml). Accessed August 2023.

United Nations Department of Economic and Social Affairs criteria for classification as a megacity. Specifically, Zhengzhou's urbanization rate surpassed 50% in 1996 and reached 70% in 2015[21], achieving this growth in approximately 20 years. By the end of 2022, the urbanization rate has reached 79.4%, transitioning into a stage focused on enhancing the quality and characteristics of urban spaces. The central urban area of Zhengzhou is characterized by high-speed of expansion, high-density of population, high-intensity of land use, super-height of buildings, and large-scale of built-up area, making it a representative example of global rapid urbanization. Consequently, its urban growth has led to socio-spatial segregation and urban environmental degradation, challenges faced by many large cities in Europe, North America, Asia, and other regions. Despite the typicality of Zhengzhou's urban development and environmental challenges, it still receives relatively little international attention.

3.1.3 A typical model of park development in the Chinese context

National policies and strategies have played a crucial role in enhancing the urban environment. As with other Chinese cities like Beijing, Shanghai, Wuhan, Nanjing, etc., Zhengzhou was recognized as a national "Landscape Garden City" due to its efforts in promoting urban greening. Subsequently, through ongoing improvement in UGSs, Zhengzhou has become the first provincial capital city situated north of the Yangtze River to be awarded the esteemed national title of "Ecological Garden City". These measures have greatly fostered the planning and construction of urban parks in Zhengzhou. There has been a considerable increase in park areas, improved balance in park layout, and the gradual formation of a multi-type and multi-level park system. These advancements exemplify a typical model of urban park development in China. Nevertheless, compared to the rapid development of Zhengzhou in terms of economy, population, and urban built-up area, the progress of the urban park system has not yet achieved a corresponding coordinated development with the urban spatial pattern. Therefore, the research on urban parks in Zhengzhou holds considerable practical implications for enhancing the quality of the urban environment, while also contributing a valuable case study of urban parks in rapidly urbanizing cities.

3.2 Study area overview

The study is focused on the central urban area of Zhengzhou (***Figure 3.1b***), covering approximately 1017 km^2, which represents about 1/7 of the total area of the Zhengzhou region. The rationale for selecting the study area, along with its geographical and social context, is

[21] Zhengzhou Municipal Bureau of Statistics website (https://tjj.zhengzhou.gov.cn/ndsj/3134558.jhtml). Accessed August 2023.

introduced in this section. Moreover, to lay the foundation for comprehending urban park development in Zhengzhou, this section outlines the historical background of the city and its policy orientations in park planning.

3.2.1 The central urban area of Zhengzhou

(1) Rationale for selecting the study area

The selection of the study area is influenced by four primary factors. Firstly, the central urban area is highly urbanized with high population density, resulting in a concentrated demand for urban parks. Secondly, a comprehensive approach is taken in terms of the UGS system plan and the urban park layout, treating the area as a unified entity. Thirdly, the central urban area serves as the epicentre of urbanization within the Zhengzhou region, providing a unique opportunity to investigate the evolving dynamics between park supply and resident demand during the dramatic urbanization process. Lastly, the decision to focus on this specific area is also driven by considerations of data consistency and availability. The study area aligns with the boundaries outlined in the Master Plan for Zhengzhou Metropolitan Area (2012-2030) and Zhengzhou UGS System Plan (2013-2030). It encompasses five administrative districts, namely Zhongyuan, Erqi, Guancheng, Jinshui, and Huiji (***Figure 3.1c***), with the New East Urban Zone, High-Tech Industrial Development Zone, as well as Economic and Technological Development Zone involved in.

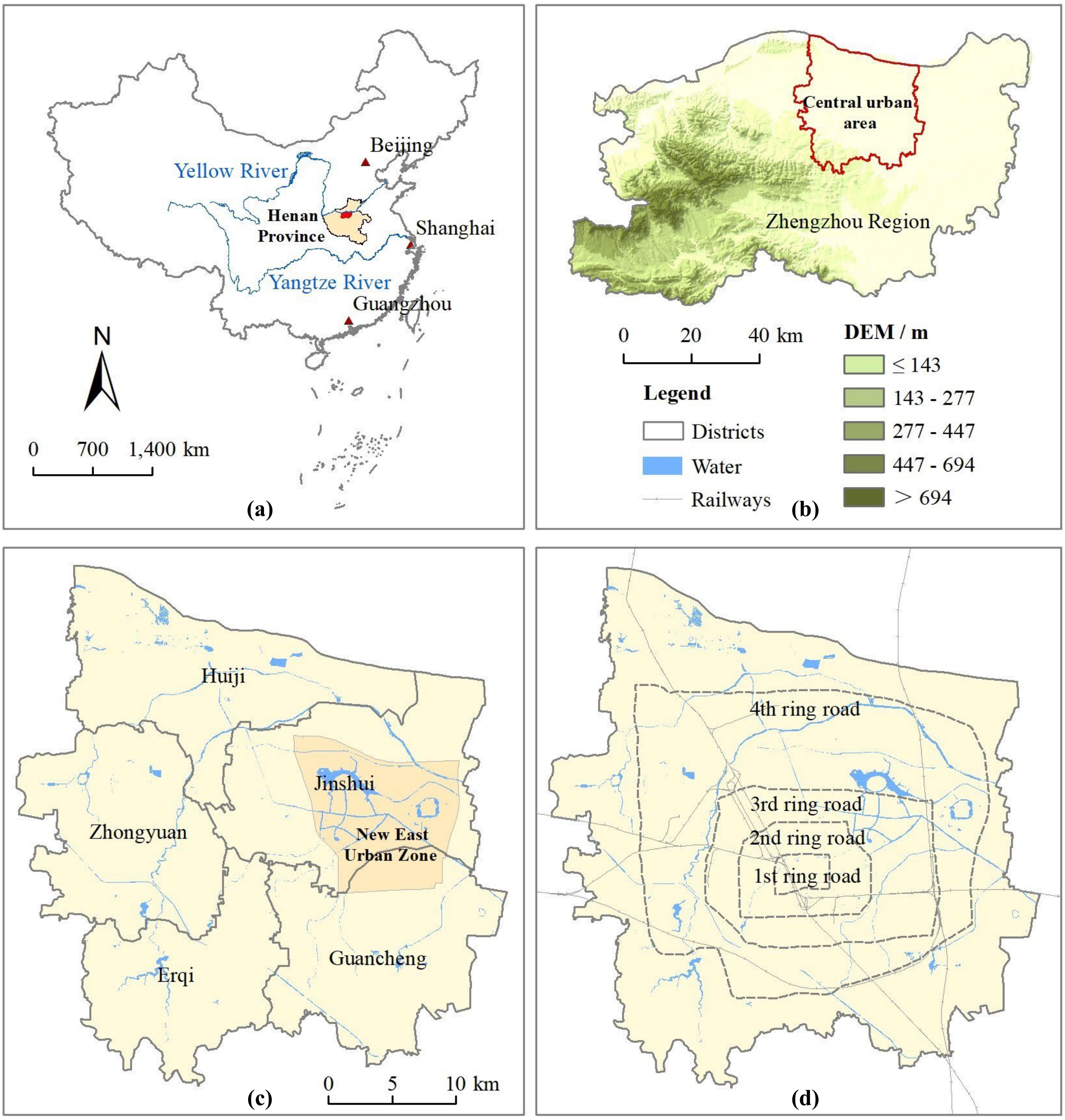

Figure 3.1: Geography, topography, and the central urban area of Zhengzhou, Henan Province (Source: Author).

(2) Geographical and social context

The central urban area of Zhengzhou is situated in the Yellow-Huai Plain, characterized by a generally flat topography. It falls under the influence of a northern temperate continental monsoon climate and features warm temperate deciduous broadleaf forest vegetation. The city has a relatively well-developed water network of rivers and lakes. The Yellow River, China's second longest river, flows through the northern border of the area, while the territory is also traversed by over 10 other rivers, such as the Jalu River, Jinshui River, Xionger, etc. These rivers belong to the two major water systems in China, namely the Yellow River and the Huai River. Furthermore, the area boasts several diverse artificial water bodies such as the South-to-North Water Diversion Canal, Dragon Lake, Xiliu Lake, Longzi Lake, Changzhuang Reservoir, Jiangang Reservoir and so on. The integrated natural and artificial water network collectively provide good ecological conditions for the establishment of waterfront parks and the development of Zhengzhou's UGS system.

The central urban area of Zhengzhou is inhabited by a population of 6.84 million (according to the 2020 census) within an area of approximately 1017 km^2. The average population density in this area is approximately 6726 individuals per km^2. During the period of dramatic urbanization in Zhengzhou's central urban area from 2000 to 2020, the population experienced significant growth, increasing from approximately 2.51 million to around 6.84 million residents, indicating a growth rate of 172.5% (according to the 2000 and 2020 censuses). Correspondingly, the built-up area expanded substantially from approximately 133.2 km^2 to 709.7 km^2, representing a growth rate of 432.8% (according to Zhengzhou Municipal Bureau of Statistics). The urban fabric expands outward in a concentric pattern, characterized by five urban rings delineated by four major urban ring roads (***Figure 3.1d***). This spatial arrangement of the new urban area surrounding the old urban area results in disparities between the old and new urban living environments. Notably, the inner two rings demonstrate higher population density, greater building density, and a lower proportion of green spaces compared to the outer rings.

3.2.2 Historical background of the city

Owing to its advantageous location in the middle reaches of the Yellow River, coupled with a favorable climate, fertile land, abundant water resources, and rich natural wealth, Zhengzhou region emerged as a thriving settlement for early inhabitants. Over time, it evolved into a central hub for the development, convergence, and assimilation of China Central Plains Culture, thus laying the foundation for the historical urban development of Zhengzhou. The history of Zhengzhou city can be traced back about 3,600 years ago when it served as the capital of the early Shang Dynasty (1600 BC-1300 BC). Archaeology have revealed that the ancient city already had a well-planned, walled, and moat-protected built-up area of approximately 25 km^2. This area consisted of the inner city and the outer city. The inner city, located north of the Xiong'er River, had a roughly rectangular plan. The Jinshui River crossed the northern part of the inner city, running horizontally through it (***Figure 3.2***).

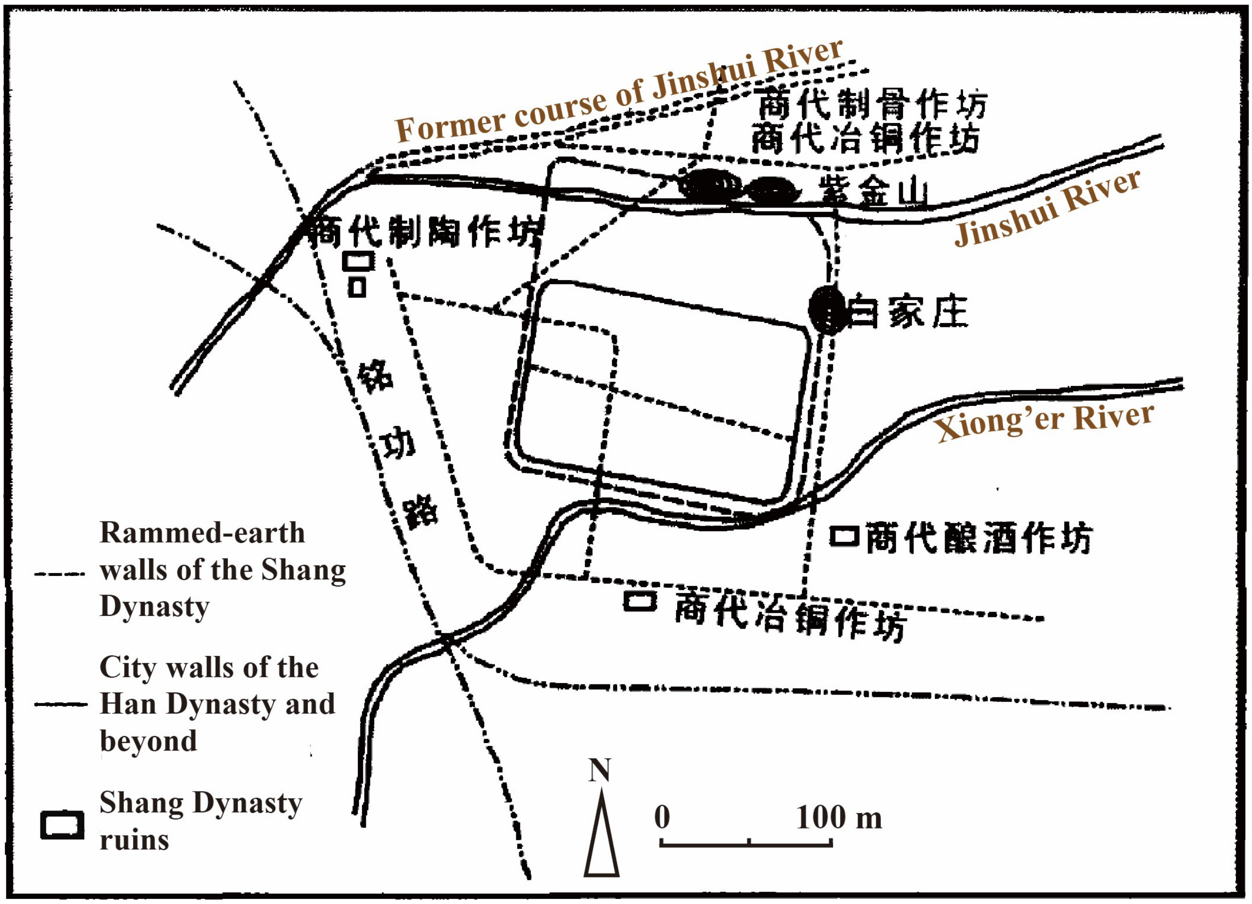

Figure 3.2: Ancient city sites in Zhengzhou from Shang (1600 BC-1046 BC) and Han Dynasties (202 BC-220 AD) (Source: Dong (2004)).

During the following over ten centuries, Zhengzhou undergone various transformations due to warfare and natural disaster. It evolved from being the capital city of the early Shang Dynasty to becoming the capital of vassal states or fiefdoms throughout the Zhou period (1046 BC-256 BC). Subsequently, it transitioned into a county town during the Qin (221 BC-206 BC) and Han Dynasties (202 BC-220 AD). According to archaeological findings, the ancient city during the Han Dynasty was smaller in size compared to the Shang Dynasty. It was constructed by modifying the eastern, western, and southern walls of the Shang Dynasty city. The ancient city was located between the Jinshui River and the Xiong'er River, with both rivers connected to the city moat, forming a comprehensive defense and supply system (***Figure 3.2***).

During the Sui Dynasty (581 AD-618 AD), the name of Zhengzhou was first officially chartered, and the city assumed the role of a prefecture, the first level administration. Subsequently, owing to its advantageous location near the capitals of Luoyang and later Bianliang (present-day Kaifeng), coupled with its strategic position along the Grand Canal, Zhengzhou emerged as a pivotal transportation hub, regaining its prosperity. However, with the southward shift of the political center of the dynasties and the decline of canal transportation, the significance of Zhengzhou gradually diminished over time. But the city of Zhengzhou continuously functioned as the seat of either a prefectural or county administration. Despite these changes that have occurred over thousands of years, it is worth noting that the scope and layout of the city of Zhengzhou has remained relatively stable until Qing Dynasty (1636 AD-1912 AD), always enclosed within the Han Dynasty city walls (***Figure 3.3***).

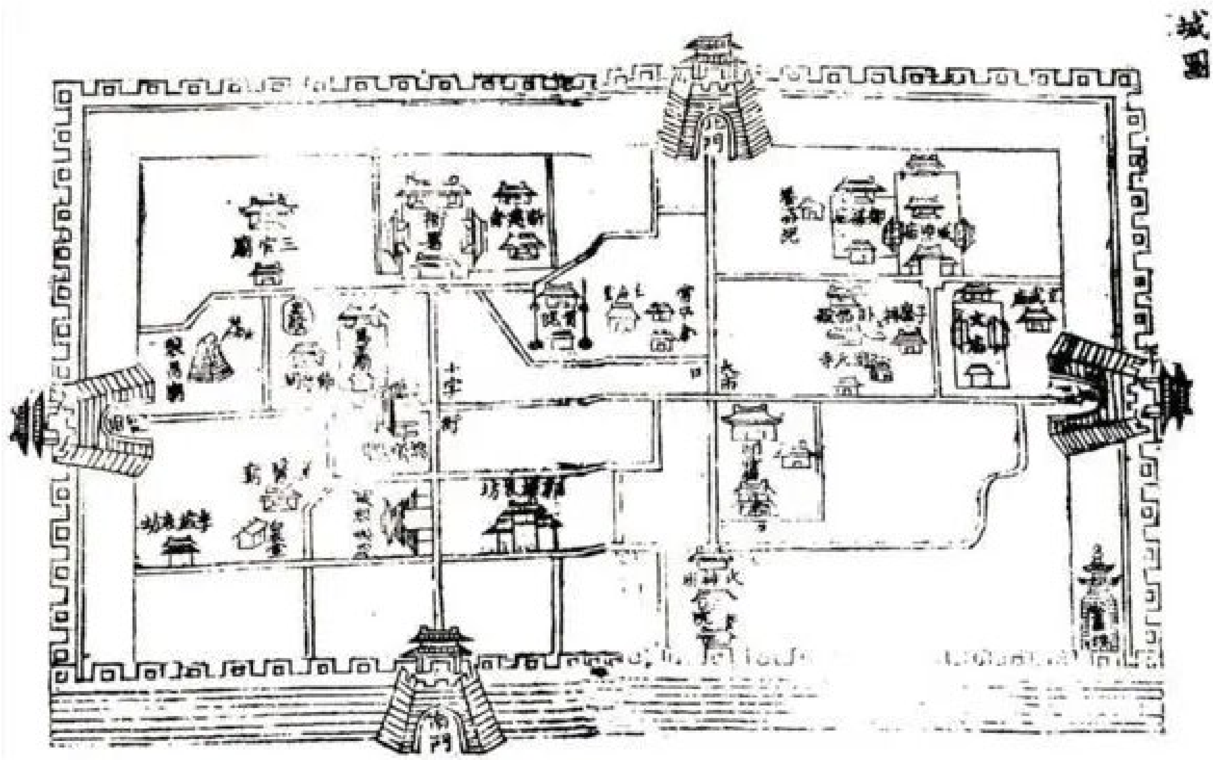

Figure 3.3: Urban spatial layout of Zhengzhou in Qing Dynasty (1636 AD-1912 AD) (Source: Toutiao website[22]).

Until the early 20th century, Zhengzhou's position as a major transportation hub was rejuvenated by the convergence of two major railways, namely Pinghan Railway and Longhai Railway, which traversed north-south and east-west across China, respectively. This strategic intersection of transportation routes propelled the city into a thriving regional center for commerce and trade. Correspondingly, Zhengzhou transcended the enduring spatial layout of its ancient city, undergoing rapid expansion between the old city and the railway station (***Figure 3.4***). This transformative process facilitated the transition from a small and underdeveloped feudal county to a state of modern urban development in Zhengzhou.

[22] Toutiao website (https://www.toutiao.com/article/6750632261986566663/?source=seo_tt_juhe). Accessed September 2023.

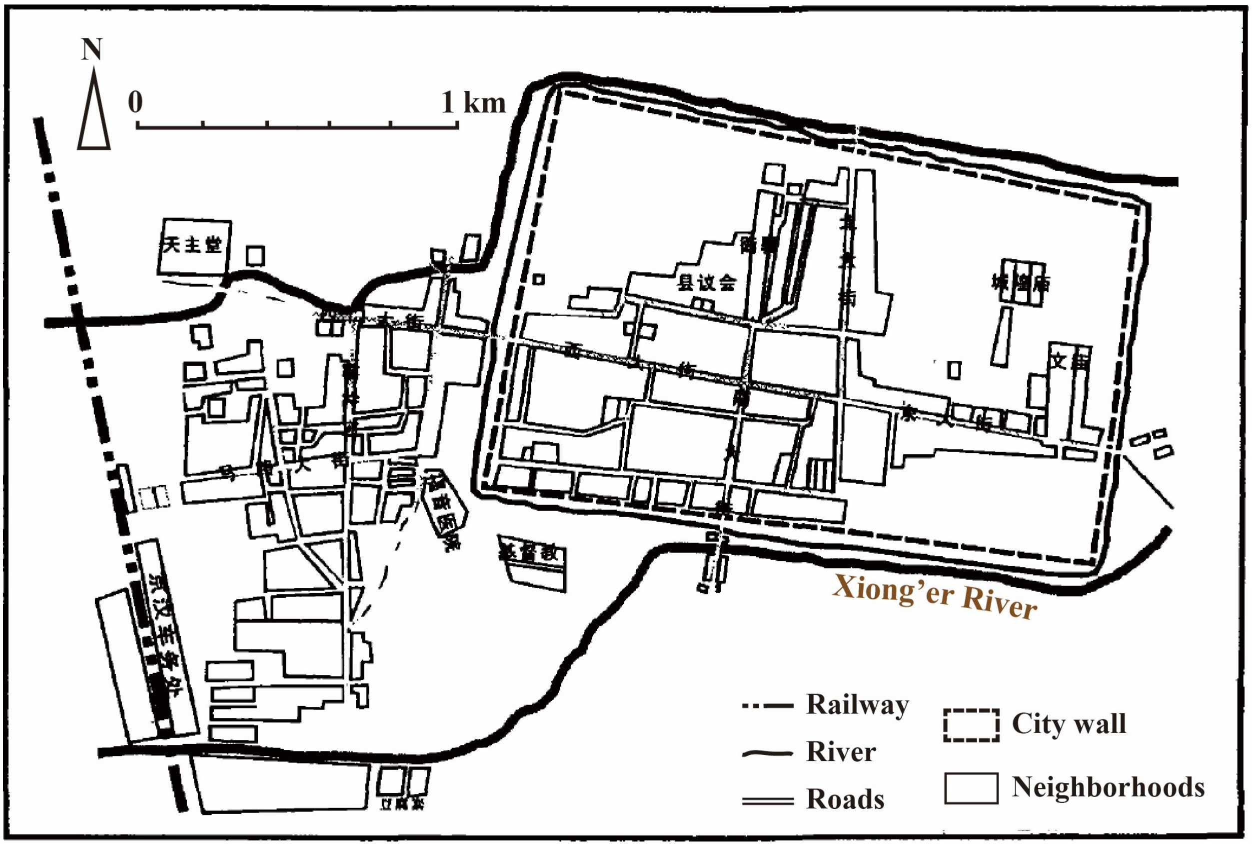

Figure 3.4: Zhengzhou city in 1905 (Source: Zheng County Annals).

In general, Zhengzhou city boasts a distinctive historical background intertwined with its unique geographical features. Remarkably, the current city center still preserves rammed-earth walls originating from the early Shang Dynasty, stretching an impressive length of approximately 7 kilometers. The city’s ongoing urban renovation efforts include a comprehensive approach that combines heritage preservation with the development of green infrastructure. To this end, a multitude of green spaces and historic parks, such as the southeast heritage park, southwest city wall heritage park, Triangle Park, and Zijingshan Park, have been established around the ancient city wall ruins (***Figure 3.5***). Consequently, these areas now serve as vibrant urban settings, blending the past with the present and offering glimpses of Zhengzhou’s rich history to contemporary urban life.

Figure 3.5: Green spaces and historic parks surrounding the city wall ruins from the early Shang Dynasty (1600 BC-1300 BC) (Source: Sina website[23] and Henan Provincial People's Government website[24], respectively).

3.2.3 Policy orientations in park planning

Regarding China's rapid urbanization process, in order to optimize the urban human living environment, a series of urban development models have been explored and promoted by the country according to different urban developmental stages and goals. Among them, "Landscape Garden City"[25], "Ecological Garden City"[26], and "Park City"[27] are progressive urban development models with various standard levels, which put an emphasis on urban greening, especially with urban park construction as an essential instrument. "Landscape Garden City" is guided by the aesthetics of urban landscape and focuses on green space construction (Chen et al. 2013). The primary indicators for evaluation include public green area per capita, green area ratio, and green coverage ratio. "Ecological Garden City" aims to build a livable city with a good ecological environment (Cheng et al. 2018, Zhang et al. 2017). It has a relatively comprehensive evaluation system, in which the park-related indicators mainly include the park area per capita, the

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[23] Sina website (http://k.sina.com.cn/article_7517400647_1c0126e4705901ttgj.html). Accessed September 2023.
[24] Henan Provincial People's Government website (https://www.henan.gov.cn/2023/06-16/2762530.html). Accessed September 2023.
[25] The Ministry of Construction of the PRC introduced the concept of "Landscape Garden City" in 1992 and later formulated the Implementation Plan for Establishing National Garden Cities and National Garden City Standards in 2000 (https://www.mohurd.gov.cn/gongkai/zhengce/zhengcefilelib/200008/20000825_156922.html). Accessed September 2023.
[26] The Ministry of Construction of the PRC initiated the establishment of "Ecological Garden City" in 2007 (https://www.mohurd.gov.cn/gongkai/zhengce/zhengcefilelib/200706/20070615_157280.html) and later formulated National Grading Standards for Ecological Garden City and Procedures for Application and Classification Review of Ecological Garden City (https://www.mohurd.gov.cn/gongkai/zhengce/zhengcefilelib/201212/20121207_212220.html). Accessed September 2023.
[27] President Xi Jinping first proposed the concept of a "Park City" during his research visit to the Tianfu New Area in Sichuan Province in 2018 (http://paper.people.com.cn/zgcsb/html/2018-03/19/content_1842698.htm). Accessed September 2023.

coverage ratio of park catchment area, and the minimum park area per capita in each urban district. Currently, "Park City" is a proposed vision, emphasizing people-centered city and ecological civilization within cities (Li et al. 2018, Wang 2018, Wu et al. 2018, Zhu et al. 2018). The evaluation indicators have not yet been determined, but a higher standard is undoubtedly expected. Like many other cities, Zhengzhou was successively guided by the concepts of "Landscape Garden City", "Ecological Garden City", and "Park City" in the developmental process, which has greatly fostered the planning and construction of urban parks (***Table 3.1***).

Table 3.1: Comparison of "Landscape Garden City", "Ecological Garden City", and "Park City" (Source: Author).

Urban development model	Year proposed	Core purpose & Focus of construction	Park-related metrics	Year Zhengzhou reached
Landscape Garden City	1992	• Aesthetics of urban landscape • Green space construction	• Per capita public green area ≥ 7 m^2 • Per capita public green area in urban center area ≥ 5 m^2 • Service radius of public green spaces larger than 1000 m^2 ≥ 500 m	2006
Ecological Garden City	2007	• A livable city with a good ecological environment • Urban ecological environment; urban living environment; urban infrastructure	• Per capita park area ≥ 12 m^2 • Minimum per capita park area in each urban district ≥ 5.5 m^2 • Coverage ratio of park catchment area ≥ 90%	2020
Park City	2018	• A harmonious coexistence between man and nature • People-centered city; ecological civilization; integration of urban park system and urban spatial pattern	Undetermined	-

Note: The standards for urban development models vary depending on the city's population, geographic region, or per capita construction land area, and they are adjusted over time. The park-related metrics for the Landscape

Garden City [28] and the Ecological Garden City [29] presented in the table are the standards applied when evaluating Zhengzhou.

Despite considerable studies about urban parks from multiple perspectives, there is little empirical evidence on the analysis and evaluation of urban park development itself from a historical and local point of view, which should be the basis for a better urban park system. Therefore, research on the developmental process of urban parks can be of significance for dealing with the current problems and future opportunities of Zhengzhou city.

3.3 Data collection and processing

The research draws upon a range of data sources, comprising both primary and secondary sources. Primary sources primarily consist of satellite imagery and multi-source big data obtained from online data platforms. In addition, archival materials, and illustrations such as maps and plans from offices, municipalities, libraries, archives, as well as measurements and photographs from fieldwork, are employed. Secondary sources encompass books, articles, and reviews from libraries and journals. Particularly, to effectively measure urban park accessibility in the central urban area of Zhengzhou, I utilize multi-source data related to supply of parks, demand of population, and travel cost.

3.3.1 Supply of parks

General geographic approach to measure park accessibility usually uses proximity and park size to represent the supply of parks, ignoring the attractiveness of different kinds of parks (Tu et al. 2020, Xiao et al. 2017, Yu et al. 2020). In addition to park size, park quality is also a key parameter, including recreational amenities, supporting facilities, natural features, maintenance, etc., that has a large impact on park visits and use (Ibes 2015, McCormack et al. 2010, Rigolon et al. 2016, Zhang et al. 2022). Only a few studies have incorporated park quality indicators including features and conditions in the assessment of park services supply (McCormack et al. 2010, Xing et al. 2020a, Zhang et al. 2022). Additionally, park category needs to be considered, as it usually determines different values of per capita park area from a design perspective, and thus affects park accessibility through varied park capacity.

In this study area, the attributes of parks, including size, category, and quality were examined to

[28] Ministry of Housing and Urban-Rural Development of the PRC website (https://www.mohurd.gov.cn/gongkai/zhengce/zhengcefilelib/200504/20050419_157127.html). Accessed September 2023.

[29] Ministry of Housing and Urban-Rural Development of the PRC website (https://www.mohurd.gov.cn/gongkai/zhengce/zhengcefilelib/201611/20161104_229393.html). Accessed September 2023.

comprehensively consider the supply effect of parks. I extracted the areas of interest (AOI) of parks through a widely used map platform in China, Amap[30]. A total of 163 UPPs in the central urban area of Zhengzhou were included, ranging from 1 ha to 374 ha in size. According to the Standard for Classification of UGSs (CJJ/T85-2017)[31], there were 41 comprehensive parks, 31 theme parks, 19 community parks, and 72 other parks (***Figure 3.6***). Comprehensive parks and theme parks are designed to attract citizens from broad urban areas, while community parks and other parks are primarily established to meet the demand of certain residential areas (***Table 3.2***). Park capacity is influenced by both park size and park category, which is expressed as the ratio of park size to per capita park area. According to Code for the Design of Public Parks (GB 51192-2016), theme parks and community parks are typically laid out with a smaller per capita park area compared to comprehensive parks and other parks. Specifically, comprehensive parks and other parks are designated with 60 m² per capita, while theme parks and community parks are designated with 30 m² per capita.

Table 3.2: Classification of UPPs in Zhengzhou (Source: Author).

Park category	**Description**	**Samples**
Comprehensive Park	Suitable for broad public visits, with rich content and well-equipped facilities for various outdoor activities	Municipal park, District park
Theme Park	Featuring specific content or form, with corresponding recreation and service facilities	Children's park, Botanical garden
Community Park	Serving residents within a specific residential area, with basic facilities for daily leisure activities	Residential park, Neighborhood garden
Other Park	Featuring linear shape or small scale, serving nearby residents with certain recreational functions	Belt park, Pocket park

[30] Amap website (https://ditu.amap.com/). Accessed October 2022.
[31] Ministry of Housing and Urban-Rural Development of the PRC website (https://www.mohurd.gov.cn/gongkai/zhengce/zhengcefilelib/201806/20180626_236545.html). Accessed October 2022.

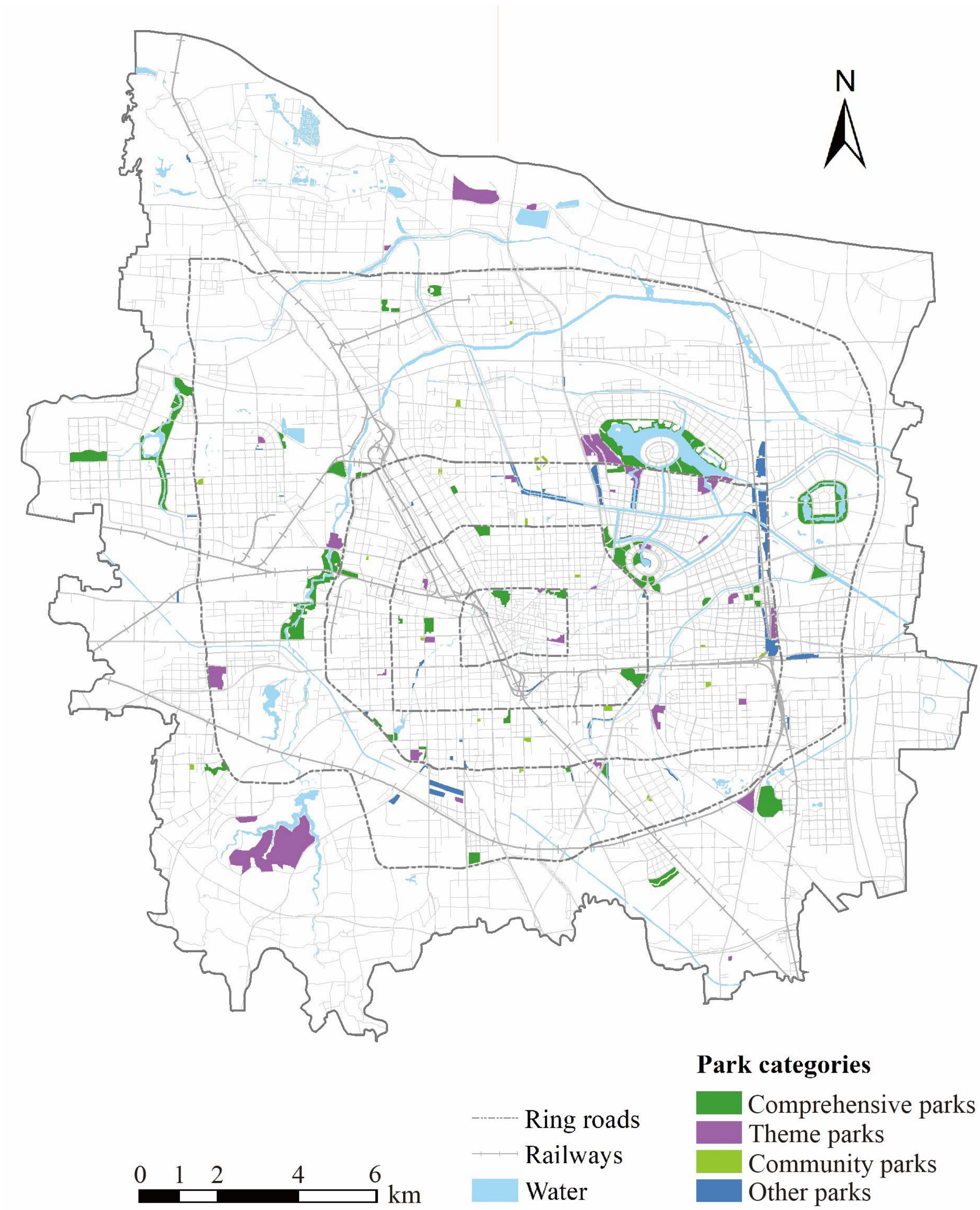

Figure 3.6: Spatial distribution of urban parks in the central urban area of Zhengzhou (Source: Author).

For park quality, I described residents' destination parks on the basis of facilities and amenities, water features, and tree canopy. According to previous studies (Ibes 2015, Lyu et al. 2019, Zhai et al. 2021), these are the major characteristics of park quality that influence park visits. Facilities and amenities were assessed regarding the presence and condition of three aspects, specified in

Code for the Design of Public Parks (GB 51192-2016)[32]: recreational amenities, service amenities, and management facilities. During on-site investigations, all selected parks were classified into five grades, from 0 to 1, representing the amenities provided as from excellent to bad facilities. The presence or absence of water bodies were identified based on fieldwork and Google Earth imagery. The ratio of tree coverage was derived from high-spatial-resolution GF-2 satellite imagery (2017), classified and calculated in ArcGIS 10.8 (***Table 3.3***). Additionally, the weights of the three variables were calculated using the Analytical Hierarchy Process (AHP) method. The park quality index is the sum of three weighted variable values for each park, expressed as follows and illustrated in ***Figure 3.7***.

$$Q_j = \sum_{i=1}^{n} W_i V_i$$

where Q_j denotes the quality index of park j; W_i is weight of variable i; V_i is the value of variable i corresponding to park j; and n is the number of variables.

Table 3.3: Variables of the park quality index (Source: Author).

Variable	Description	Scores	Weight
Facilities and amenities	Recreational amenities; Service amenities; Management facilities	Excellent as 1; Good as 0.75; Fair as 0.5; Poor as 0.25; Bad as 0	0.8421
Water features	Presence of water bodies	Yes as 1; No as 0	0.1053
Tree canopy	The ratio of tree coverage	≥50% as 1; <50% as 0.5	0.0526

[32] Ministry of Housing and Urban-Rural Development of the PRC website (https://www.mohurd.gov.cn/gongkai/zhengce/zhengcefilelib/201703/20170301_230801.html). Accessed October 2022.

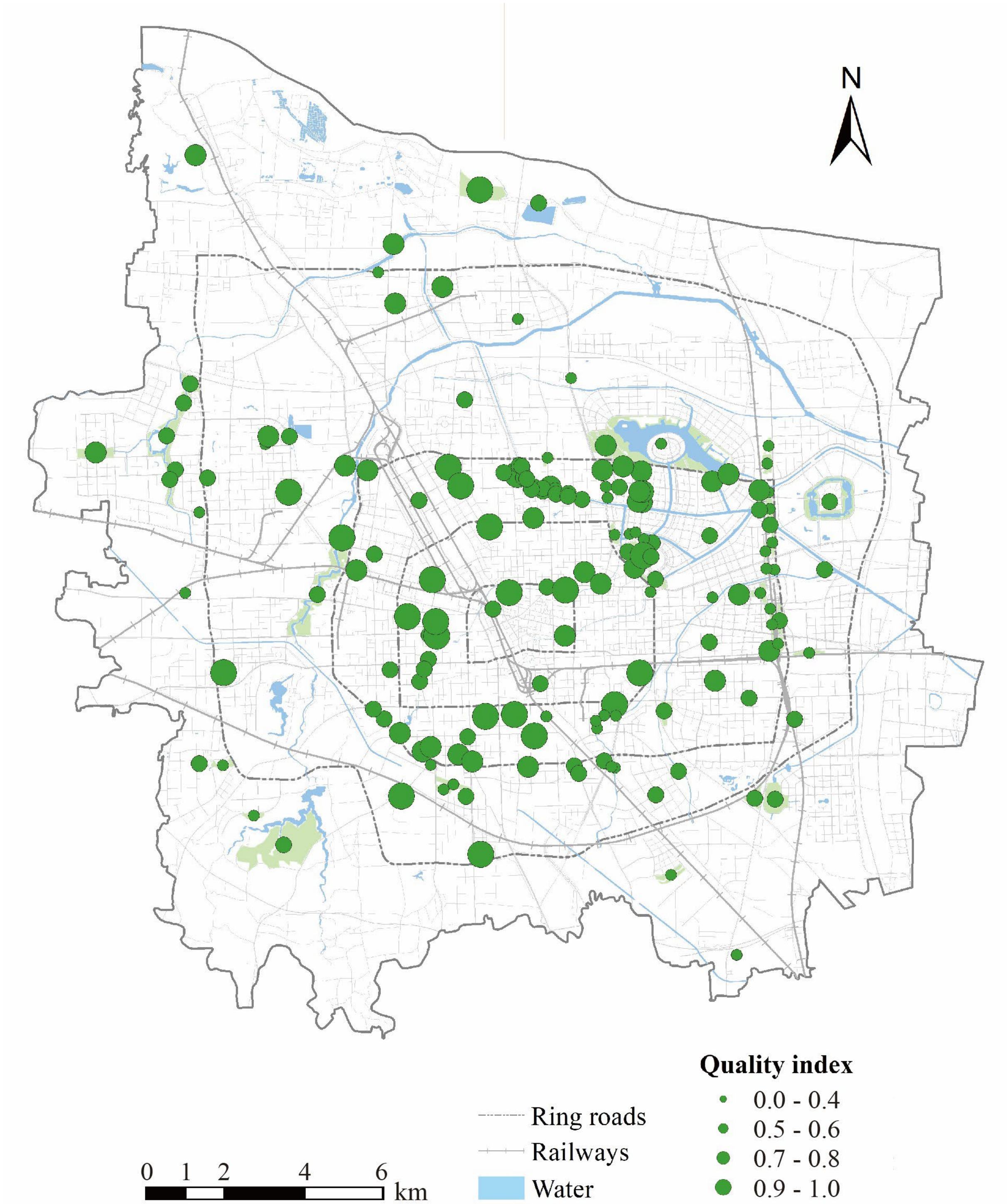

Figure 3.7: Spatial distribution of park quality index in the central urban area of Zhengzhou (Source: Author).

Given that actual entrances can affect the scope of services provided by parks, multiple entrances to each park were used as supply points rather than geographic centroids (Boone et al. 2009, Nicholls 2001, Niu et al. 2019). Through Google Earth image recognition combined with on-site investigations, a total of 864 entrances of these parks were identified.

3.3.2 Demand of population

The difficulty of current accessibility research lies in obtaining high-precision demand data. Estimates of population demand from existing accessibility studies in China rely primarily on census data. However, the census data are aggregated on a relatively rough scale, such as at the district and sub-district level, which is difficult to match with the actual layout scale of urban parks, thus affecting the accurate assessment of accessibility differences and identification of underserved areas in cities. Therefore, population data of small-scale units (e.g., communities and neighborhoods) are needed to reveal the details of variations more effectively in park accessibility.

In this study area, the centroid of each neighbourhood was used to reflect the demand location of potential visitor population of parks. The neighbourhood population was calculated and aggregated at residential building level. The AOI data of neighbourhoods and residential buildings were obtained through Baidu Maps, one of the most popular Chinese map platforms[33]. In the central urban area of Zhengzhou, a total of 4180 neighbourhoods and 49,397 residential buildings were identified after data screening and cleaning. The residential building data includes the footprint area and the number of floors. According to the 2019 Zhengzhou Statistical Yearbook, the per capita living area is 31 m^2. Thus, the number of residents in each neighbourhood were estimated as follows. The calculated total population of each district has been verified to be roughly in line with the 2019 demographic data. The corresponding population density is shown in the ***Figure 3.8***.

$$P = \sum_{l=1}^{n} \frac{S_l N_l}{R}$$

where P denotes the potential population of the neighborhood; S_l is the footprint area of each residential building l in the neighborhood; N_l is the number of floors corresponding to each residential building l; R is the per capita living area; and n is the number of residential buildings in the neighborhood.

[33] Baidu Maps website (https://map.baidu.com/). Accessed October 2022.

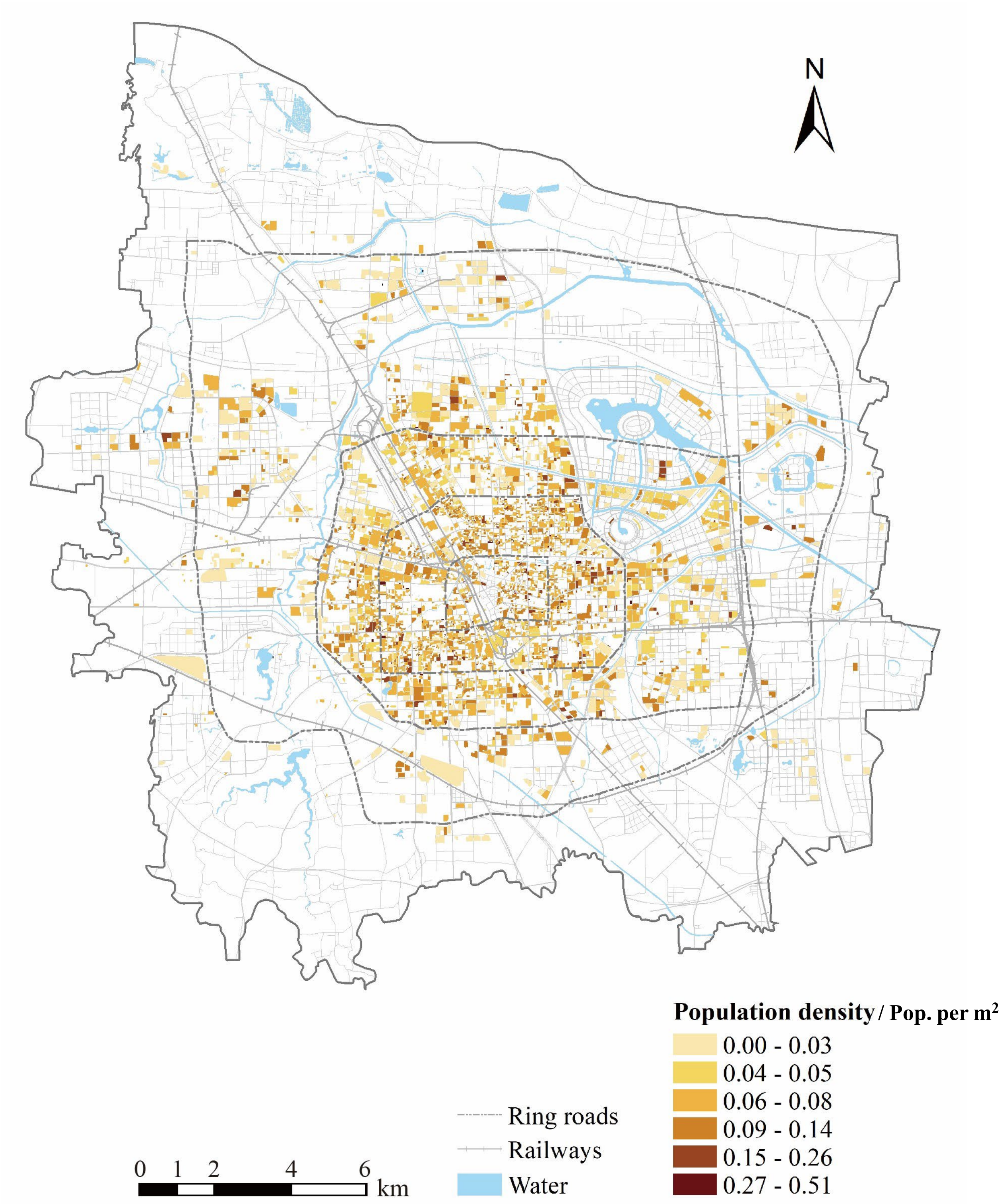

Figure 3.8: Spatial distribution of population density in the central urban area of Zhengzhou (Source: Author).

3.3.3 Travel cost

Travel cost is one of the key factors in measuring park accessibility (García-Albertos et al. 2019, Weiss et al. 2018). Traditionally, it is mainly measured by travel distance based on the road network analysis through GIS. However, this approach ignores actual traffic conditions and thus may lead to deviations from reality. To address this limitation, the application programming interface (API) of open map service was introduced to provide real-time navigation data on travel time. On the one hand, focusing on travel time rather than travel distance is more in line with social reality. In this way, on the other hand, travel cost measurement between origin and destination points can reflect factors that affect actual travel time and speed, such as traffic congestions, speed limits, turn restrictions, and other conditions (Chen et al. 2017, Hao et al. 2017, Rong et al. 2020). Given more accurate and convenient measurement compared to traditional methods, it has gradually been applied to collect travel cost data in recent park accessibility studies (Li et al. 2019, Tu et al. 2020, Yang et al. 2020).

In this study area, travel time was obtained using the API service of Baidu Maps based on the actual travel situation between two geographic locations. Taking the entrances of 163 parks as destination points and the centroids of 4180 neighborhoods as origin points, I collected the optimal time cost of several travel paths from each neighborhood to the different entrances to each park in walking mode. ***Figure 3.9*** presents an example visualization where path 1 takes the shortest time from the neighborhood to the park, and thus 9 min is filtered into the database. Walking is the main mode for urban residents to reach the parks on a daily basis. The travel time threshold, t_0, was designated as 30 min, since this represents the maximum time that can be widely accepted for routine park visits (Xing et al. 2020a, Yang et al. 2020). While real-time traffic conditions can affect the travel time by public transport and driving even on the same travel route, the actual time cost is less affected when walking on sidewalks. Therefore, the variation in acquisition time due to the large amount of data made little difference for my results.

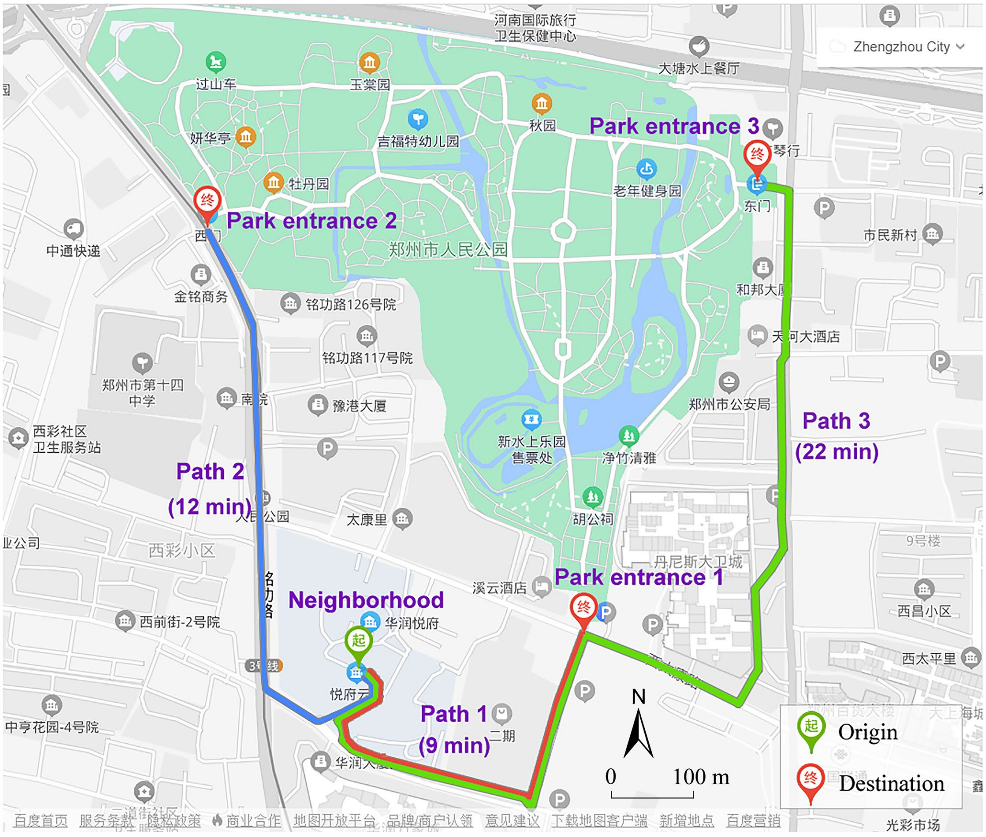

Figure 3.9: Example of travel path and time cost visualization in walking mode of Baidu Maps Navigation (Source: Author).

3.4 Measurement and assessment method

The 2SFCA method has been extensively applied to assess the accessibility and equity of public facilities and services, thereby forming a crucial foundation for my research. Drawing upon a review of the classic 2SFCA model and its extensions, this section develops an improved 2SFCA method for measuring park accessibility. Following this, to further examine the characteristics and causes of accessibility distribution, K-means cluster analysis is utilized to scrutinize influencing factors of accessibility.

3.4.1 2SFCA method overview

3.4.1.1 The classic 2SFCA model

The 2SFCA method was initially introduced by Radke and Mu (2000). Subsequently, this method was enhanced and formally named by Luo and Wang (2003). Its basic procedure comprises two steps: firstly, for each supply location j, search all demand locations (k) that are within a threshold travel distance/time (d_0) from location j, and compute the supply-to-demand ratio, R_j, within the catchment area; secondly, for each demand location i, search all supply locations (j) that are within the threshold travel distance/time (d_0) from location i, and sum up the supply-to-demand ratios, R_j, at these locations (Luo et al. 2003):

$$A_i = \sum_{j \in \{d_{ij} \leq d_0\}} R_j = \sum_{j \in \{d_{ij} \leq d_0\}} \frac{S_j}{\sum_{k \in \{d_{kj} \leq d_0\}} P_k}$$

where A_i represents the accessibility at demand location i based on 2SFCA method; i represents demand location; j represents supply location; d_{ij} is the travel distance/time between i and j; R_j is the supply-to-demand ratio at supply location j whose centroid falls within the catchment (that is, $d_{kj} \leq d_0$); S_j is the supply scale at location j; P_k is the demand scale at location k whose centroid falls within the catchment (that is, $d_{kj} \leq d_0$).

3.4.1.2 2SFCA model extensions

With the development of applications, a range of extensions to the classic 2SFCA model have emerged, which can generally be classified into four categories (***Table 3.4***), as outlined by Tao and Cheng (2016).

a) They introduce a distance-decay function, substituting the original dichotomous distance-decay function with a multilevel discrete format in Enhanced 2SFCA, or with continuous forms of distance decay as illustrated in the Gravity 2SFCA, Gaussian 2SFCA, and Kernel Density 2SFCA.

b) They optimize the catchment area delineation, moving away from the traditional buffer-ring method with certain search radii. The search radii are determined based on factors such as search efficacy relative to supply and demand scales in Variable 2SFCA, population density in Dynamic 2SFCA, and facility scale tiers in Multi-catchment Sizes 2SFCA. Additionally, catchment areas in Nearest Neighbor 2SFCA are defined by identifying a finite number of the nearest facilities for each demand location.

c) They incorporate demand or supply competition. 3SFCA adds an additional search step to calculate the selection weight, followed by Modified 2SFCA considering the locational availability of facility resources and Huff 2SFCA using huff model to consider the impact of both travel cost and facility service on travel choices. Moreover, Optimized 2SFCA is based on actual user count for the facilities from the previous year.

d) They extend the travel means considered, encompassing Multi-mode 2SFCA taking into account multiple potential transportation modes, and Commuter-based 2SFCA incorporating aspects of service visits and commuting behavior.

Table 3.4: Major extensions to the 2SFCA model (Source: Adapted from Tao et al. (2016)).

Extension categories	Extension forms	Major extensions & Key literature
Introduction of a distance-decay function	Enhanced 2SFCA	Segmenting the distance-decay function by distance (Luo et al. 2009).
	Gravity 2SFCA	Introducing the distance-decay function of gravity model, such as power, exponential, and logarithmic functions (Tao et al. 2014, Wang et al. 2013).
	Gaussian 2SFCA	Incorporating a Gaussian function as the distance-decay function (Dai 2010, 2011).
	Kernel Density 2SFCA	Incorporating a Kernel density function as the distance-decay function (Dai et al. 2011).
Optimization of the catchment area delineation	Variable 2SFCA	Adjusting the radii for the two-step search separately to ensure that the search radius for facilities encompasses a sufficient scale of demand, and the search radius for demand locations accesses a basic scale of facility resources (Luo et al. 2012).
	Dynamic 2SFCA	Establishing catchment sizes based on regional population density for application in urban-rural interface areas (McGrail et al. 2014).
	Multi-catchment Sizes 2SFCA	Setting different search radii based on facility scale tiers, with larger facilities having correspondingly larger catchment areas (Tao et al. 2014).
	Nearest Neighbor 2SFCA	Proposing a method for delineating the catchment areas by identifying a finite number of nearest facilities for each demand location (Jamtsho et al. 2015).
Incorporation of demand or supply competition	3SFCA	Adding an additional search step to calculate the selection weight between demand locations and facilities, aimed at assessing the competitive effects among multiple facilities within the same catchment area of a demand location (Wan et al. 2012).
	Modified 2SFCA	Allowing for the scenario where some facility resources are underutilized by demand locations due to inefficient spatial allocation. This is addressed by implementing an additional distance-decay in the E2SFCA model (Delamater 2013).
	Huff 2SFCA	Using the huff model, further adjustments are made to the selection weight variables of 3SFCA to comprehensively consider the impact of both travel costs and facility service capacity on travel choices (Luo 2014).
	Optimized 2SFCA	Using the actual number of users at each facility from the previous year as the potential user count for the facilities has been implemented to enhance the consideration of competition from multiple demand locations for the same facility resources (Ngui et al. 2011).

Extension of the travel mean consideration	Multi-mode 2SFCA	Correction of the travel time in the traditional 2SFCA, which originally used a single transportation mode, has been carried out by employing a weighted average travel time among multiple transportation modes (Mao et al. 2013).
	Commuter-based 2SFCA	Considering the impact of commuting behavior on the accessibility of public services, the demand scale is calculated based on commuting behavior (Fransen et al. 2015).

Through a series of explorations in the above aspects, the rationality of 2SFCA method has been significantly improved. Notably, each extension has its features, with its appropriateness influenced by the attributes of facility resources and the context of opportunity usage in the study area. In the empirical research (refer to Section 4.2), an improved 2SFCA method is developed to measure the accessibility of UPPs in Zhengzhou, China. The following improved method integrates the distance-decay function from the Gaussian 2SFCA and the demand/supply competition of the Huff 2SFCA.

3.4.2 Improved 2SFCA method

The improved 2SFCA method aims to provide an overall measurement of park accessibility by comprehensively considering the supply of public parks (including park size, category, and quality), the demand of neighborhood residents, travel costs, and residents' selection probability.

In terms of supply, urban parks with higher quality levels and greater service capacity are positively correlated with higher rates of park access and use. Therefore, instead of relying solely on park size, I applied the attraction coefficient S_j, which combines park quality and park capacity to comprehensively reflect the supply effect of parks. This enhanced model is expressed as follows.

$$S_j = \frac{A}{A_m} Q_j \tag{1}$$

where S_j denotes the attraction coefficient of park j; A is the park size of park j; A_m is the per capita park area corresponding to the category of park j; and Q_j is the quality index of park j.

The spatial distribution of the park attraction coefficient in the central urban area of Zhengzhou is shown in ***Appendix 5***, while the attributes of UPPs are detailed in ***Appendix 6***.

The Gaussian decay function (Dai 2011) was developed to solve spatial friction problems. It can reflect the law that the relation between supply and demand weakens with the increase in spatial distance. In addition, it is widely used in spatial accessibility measurement of parks, expressed as follows.

$$G(t_{ij}) = \begin{cases} \dfrac{e^{-(1/2)\times(t_{ij}/t_0)^2} - e^{-(1/2)}}{1 - e^{-(1/2)}} & (t_{ij} \le t_0) \\ 0 & (t_{ij} > t_0) \end{cases} \tag{2}$$

Given the competition among multiple available parks, recent improved models have only considered the impact of travel impedance on both demand of population and supply of parks (Niu et al. 2019, Tong et al. 2021). However, in addition to travel cost, differences in supply effects among multiple available parks can also affect residents' selection probability. Residents may prefer to visit parks with not only shorter travel time, but also greater appeal. To address this issue, Luo (2014) drew on a Huff model to improve the selection weights by introducing park capacity together with travel impedance, without considering park quality. Xing (2020a) developed the selection probability involving park attractiveness, travel cost, and travel impedance, while the impact of distance decay was doubled into account. I refined the selection probability $Prob_{kj}$ of residents in a neighborhood among multiple available parks to improve the weighted estimation of potential demand and supply, as shown below.

$$Prob_{kj} = \frac{S_j G(t_{ij})}{\sum_{k\in\{t_{kj}\le t_0\}} S_j G(t_{ij})} \tag{3}$$

Therefore, in the first step, through travel impedance coefficient $G(t_{ij})$ and selection probability coefficient $Prob_{kj}$, the population of neighborhoods within the travel time threshold of each park was adjusted, and then summed to represent each park's potential visitors. The supply-to-demand ratio R_j for each park is defined as follows.

$$R_j = \frac{S_j}{\sum_{k\in\{t_{kj}\le t_0\}} Prob_{kj} P_k G(t_{ij})} \tag{4}$$

In the second step, the supply-to-demand ratio corresponding to the parks within the travel time threshold of each neighborhood was calculated and weighted by travel impedance coefficient $G(t_{ij})$ and selection probability coefficient $Prob_{kj}$. These weighted supply-to-demand ratios were then summed to obtain park accessibility A_i for each neighborhood, as shown below.

$$A_i = \sum_{j\in\{t\le t_0\}} Prob_{kj}\, R_j G(t_{ij}) \tag{5}$$

In Formulas (2)-(5), above, $Prob_{kj}$ denotes the selection probability of population at k visiting park j; S_j is the attractiveness of park j; t_{kj} is the travel time from k to j; t_0 represents the travel time threshold; $G(t_{ij})$ is the travel impedance coefficient; R_j denotes the supply-to-demand ratio of park j; P_k is the population of neighborhood k; and A_i denotes the park accessibility in neighborhood i.

The supply-demand improved 2SFCA method integrates actual factors affecting residents' access to urban parks by utilizing data from multiple sources, with a specific emphasis on the attraction coefficient of parks and selection probability of residents. This comprehensive method is expected to significantly enhance the accuracy of park accessibility measurement, encompassing improvements in both the model and the data utilized.

3.4.3 K-means cluster analysis

Most of the literature on equity assessment has emphasized the identification of distributional disparity and underserved areas within the study area, while failing to examine how the spatial differences exist? To advance comprehensive and systematic equity research, as well as targeted strategy development, it is necessary to investigate spatial patterns of supply, demand, and accessibility.

Based on neighborhood-scale spatial accessibility, I performed a cluster analysis to identify various accessibility types and regions as well as explore spatial similarities and differences in park accessibility. In various cluster analysis methods, K-means is extensively applied because of its simplicity and efficiency. I adopted it to cluster the major factors with respect to supply, demand, and accessibility, including accessibility, average travel time, population density, total park size, and total park quality index (***Table 3.5***). By trying different clustering schemes for three to eight categories, respectively, in SPSS 27, the appropriate number of clusters was determined. Then, the results were imported into ArcGIS 10.8 for spatial visualization. The clusters can reflect accessibility patterns as well as explain the causes behind spatial accessibility differences.

Table 3.5: Factors involved in clustering (Source: Author).

Factor	Description
Accessibility	Accessibility value calculated for each neighborhood by improved 2SFCA method
Average travel time	Average travel time to parks within a 30-min walk of each neighborhood
Population density	The ratio of the population of each neighborhood to the corresponding neighborhood area
Total park size	Total area of parks within a 30-min walk of each neighborhood
Total park quality index	Total quality index of parks within a 30-min walk of each neighborhood

4 RESULTS AND DISCUSSION

4.1 Developmental process and characteristics of Zhengzhou's UPPs

To outline the developmental process and characteristics of Zhengzhou's UPPs, the research questions are threefold: **a)** What phases have urban parks in Zhengzhou gone through? **b)** What are the evolution trends? **c)** What developmental strategies can be formulated? This study was primarily conducted using qualitative and inductive methods. We first applied empirical analysis based on text and illustrations to outline four progressive phases according to the city's developmental stages and green space developmental opportunities. Then I reviewed the evolution trends from the perspective of implementation approaches, spatial layout, functions and uses, and sustainability and nature-based solutions. The last part discussed the development issues and strategies regarding land use approaches, user group needs, and public participation. The overview of urban park development in Zhengzhou may help formulate adaptive and effective policies and planning tools for urban parks and provide a basis for further research on urban parks and Zhengzhou's path to the ideal "Park City".

4.1.1 Developmental phases of urban parks

During the first half of the 20th century, it is worth mentioning that several major green spaces were developed by the local government in conjunction with the growth of the city. Pingmin Garden, with an area of 8 acres, was first constructed for residents to visit, but it was eventually abandoned. Then Bishagang Cemetery was established in 1928 to commemorate the martyrs, later converted into the urban park with the longest history in Zhengzhou. And there was a green space centered around Penggong Temple, where the first real urban park was established later. Besides, Longhai Garden covering an area of 75 acres, was laid out in a nursery in 1934 for citizens to relax and enjoy, which was later changed. However, a prolonged period of warfare followed, including the Second Sino-Japanese War and the Chinese Civil War, Zhengzhou's urban development was hindered. By the time of its liberation in 1948, Zhengzhou remained a dilapidated small county with poor urban infrastructure and a worn-out appearance. There were only a few green spaces, including Longhai Garden, Bishagang Cemetery, the green space of Penggong Temple, and several private gardens, while street trees in the city were also scarce. Furthermore, frequent sandstorms plagued Zhengzhou due to the accumulation of sand caused by floods, earning it the moniker of the "Sandy City" (Zhengzhou Municipal People's Government 1997). After the founding of PRC in 1949, Zhengzhou entered a development era and started urban construction. Notably, to improve the urban environment and change the city's image, a large number of trees were planted continuously in the urban area at the call of the municipal government. By 1985, the green coverage rate had reached 35.25%, which earned Zhengzhou a reputation as a "Green City" (***Figure 4.1***).

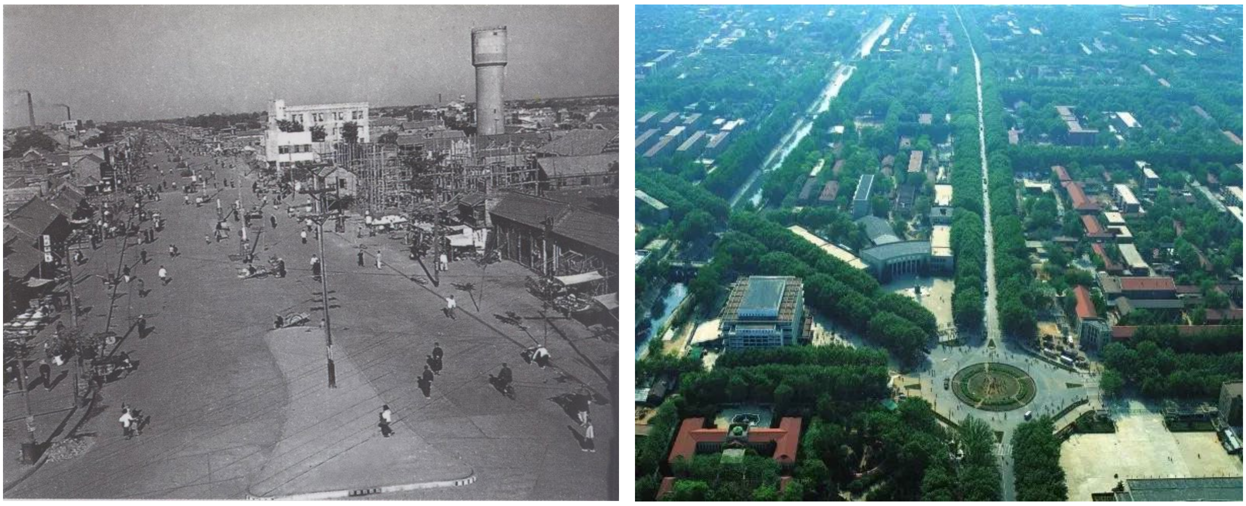

Figure 4.1: Comparison of "Sandy City" image from the 1950s and "Green City" image from the 1980s (Source: Dahebao website[34] and Sohu website[35], respectively).

Over the past decades, Zhengzhou has undergone rapid urbanization with tremendous changes in population and built-up land in the central urban area. This urban transformation has brought about great development in UGSs, particularly urban parks, through multiple rounds of urban planning and UGS system planning. According to statistical data, the area of urban parks has experienced significant and rapid growth, expanding from none in 1948 to a total of 4,328 hectares by 2018 (***Figure 4.2***). As of 2019, Zhengzhou boasted a per capita park area of 14.5 m^2 (Zhengzhou Municipal Bureau of Statistics), which was at a relatively high level compared with the per capita park area of 8.4 m^2 in Shanghai (Shanghai Municipal Bureau of Statistics).

[34] Dahebao website (http://www.dahebao.cn/news/1403410?cid=1403410). Accessed May 2021.
[35] Sohu website (http://news.sohu.com/a/679457935_121687414). Accessed May 2021.

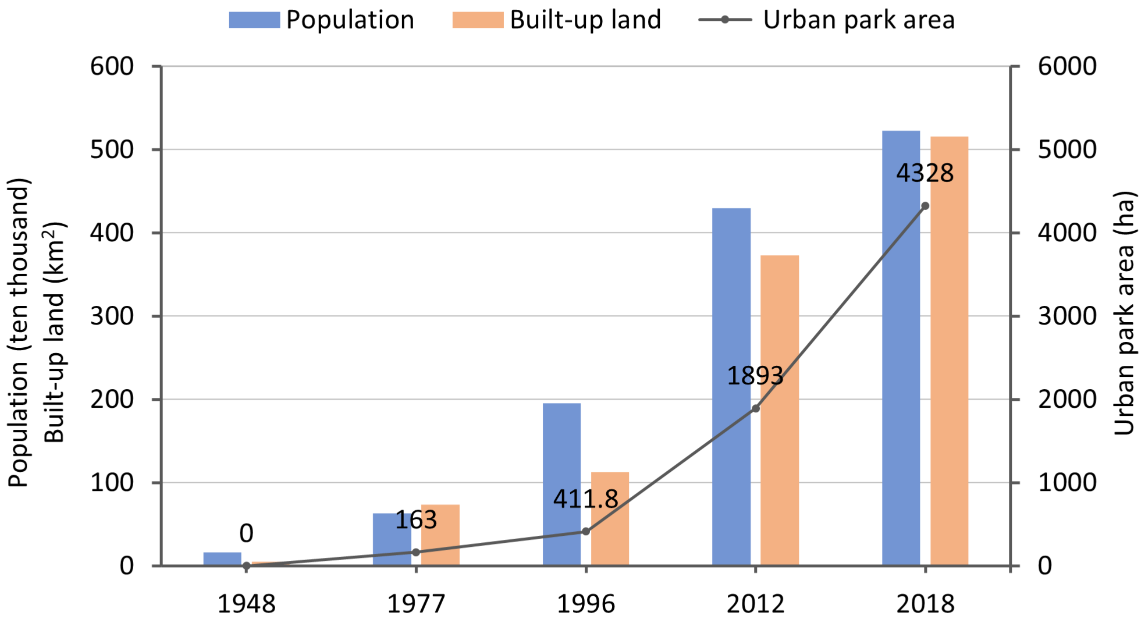

Figure 4.2: Changes over the years in population, built-up land, and urban park area in the central urban area (Source: Zhengzhou Statistical Yearbook).

4.1.1.1 The emergence phase (1949-1977)

a) Zhengzhou was transformed into the capital city of Henan Province in 1954, which brought unprecedented opportunities for urban development.

b) After the founding of PRC in 1949, the country began to attach importance to people's leisure and recreation activities. Therefore, the construction of urban parks received support from the municipal government.

For Zhengzhou, the urban park was just an unfamiliar concept until 1952 when People's Park was established near the first planned city center with historical temples preserved (***Figure 4.3***). Subsequently, in 1957, Bishagang Park was converted from the original martyr's cemetery to be a landmark of another newly established city center. Then in 1964 Zijingshan Park emerged based on an ancient urban district from the Shang Dynasty (***Figure 4.4***).

Figure 4.3: People's Park in the 1970s

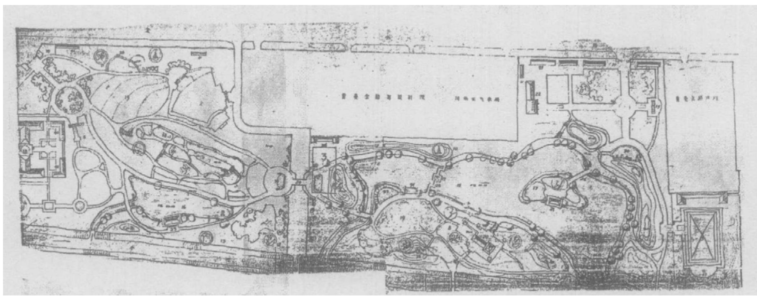

Figure 4.4: Planning of Zijingshan Park in 1965 (Source: Zhengzhou Municipal Archives).

(Source: Sohu website[36]).

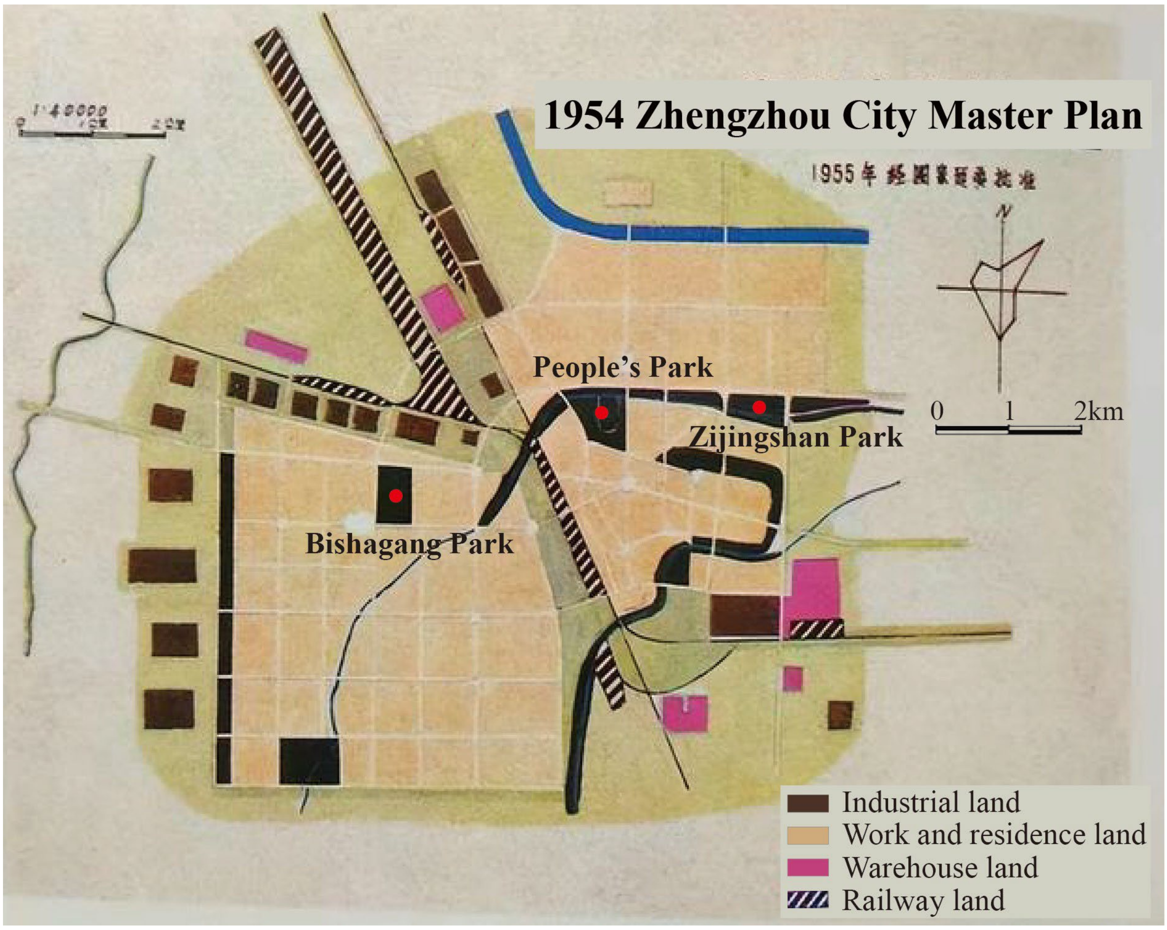

Figure 4.5: The 1954 Zhengzhou City Master Plan (Source: 163 website[37]).

The implementation of the original urban parks mainly relied on municipal government investment, including the transformation of special green spaces and historic open spaces. The three urban parks were all created as municipal-level parks to attract citizens from the whole city. That is why they were located at the critical nodes within the urban layout, as illustrated in the 1954 Zhengzhou City Master Plan (***Figure 4.5***). They were all multifunctional parks, combining culture with leisure and social activities. Moreover, under the guidance of policies, urban parks usually also played a role in agricultural production.

Urban parks in Zhengzhou can be traced back to the implementation of the first three comprehensive park initiatives. All of them have played a vital role in urban life and have earned a high reputation among the citizens. They also constitute an essential component of the urban image of Zhengzhou.

4.1.1.2 The growth phase (1978-1996)

[36] Sohu website (http://mt.sohu.com/20160910/n468154602.shtml). Accessed May 2021.
[37] 163 website (https://www.163.com/dy/article/G6AV5MFU052890RN.html). Accessed May 2021.

a) Driven by economic reform and opening-up policies proposed in 1978, the national economy progressively underwent a historic transformation from a centrally planned to a market economy, which significantly promoted urbanization.

b) With a fundamental change in land development, land prices became a key factor in determining the urban spatial layout (Xu 2007). The 1982 Zhengzhou City Master Plan designated some public green spaces around industrial and residential areas (***Figure 4.6***).

Since urban parks do not have an obvious role in generating economic benefits, it is difficult to reserve land for them through a purely market competition mechanism (Wolch et al. 2014). The Management Regulations for the Construction of UGSs in Zhengzhou was promulgated by the municipal government to ensure developmental opportunities for green spaces, including guaranteeing required land and funds, supervising illegal occupation, etc. The area of urban parks increased by nearly 250 ha from 1977 to 1996.

A few new urban parks were provided at essential locations, such as Shang City Park along ancient city wall and Xintongqiao Park beside the main road overpass. Moreover, running through the central urban area, Jinshui River was an important but long-term polluted river. As part of an improvement project, the first belt-shaped riverside park was planned and developed here to enhance the urban environment and create leisure space for citizens (***Figure 4.7***). On the whole, some critical scattered spots and linear areas were given priority to develop into urban parks.

In order to create leisure landscapes, plant design in urban parks was in focus. And, for exploiting economic benefits, urban parks increasingly accommodated diverse commercial facilities for amusement (***Figure 4.8***). It can be said that leisure and amusement played a major role in urban parks.

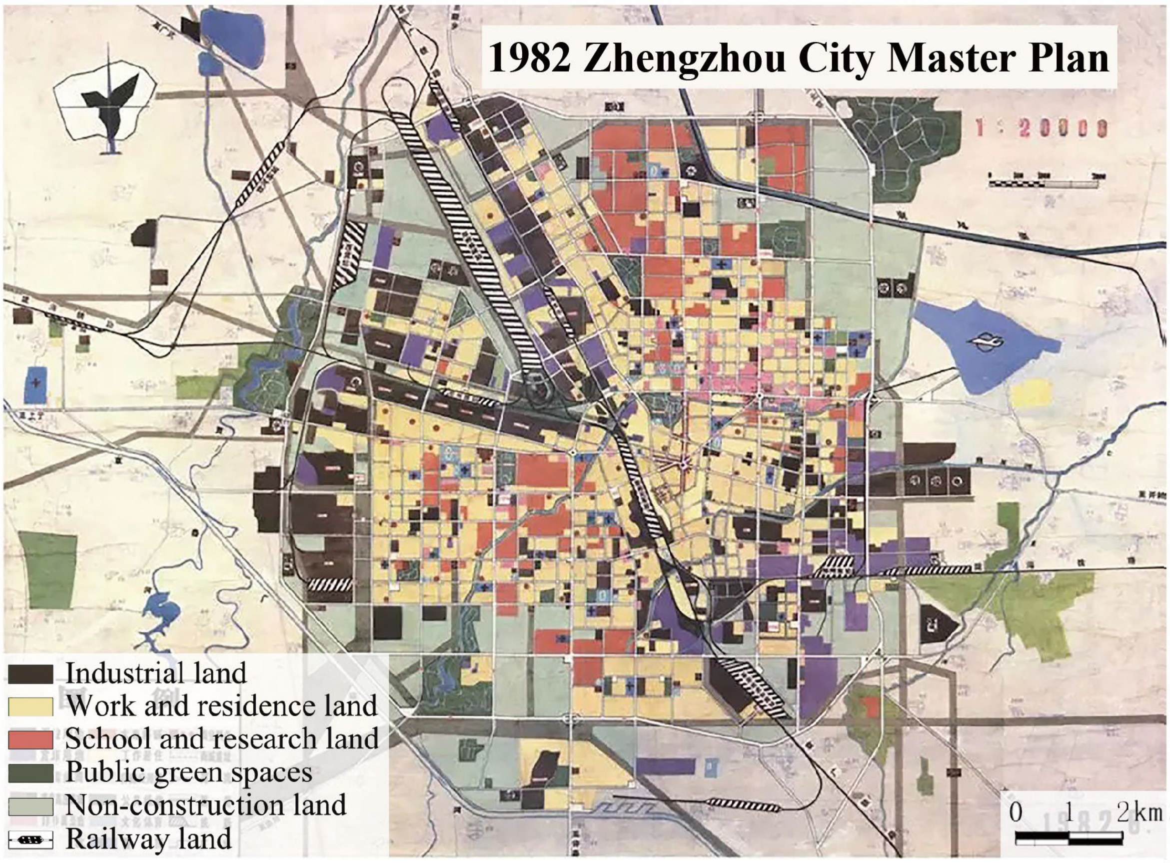

Figure 4.6: The 1982 Zhengzhou City Master Plan (Source: 163 website[38]).

Figure 4.7: The belt-shaped park along Jinshui River (Source: Tencent website[39]).

Figure 4.8: Amusement facilities in Bishagang Park in the 80s (Source: Sohu website[40]).

4.1.1.3 The acceleration phase (1997-2012)

a) The municipal government made a major strategic decision in 2000 to build a "Regional Central City", which greatly accelerated the urbanization of Zhengzhou.

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[38] 163 website (https://www.163.com/dy/article/DIJFE70O051794R7.html). Accessed May 2021.
[39] Tencent website (https://new.qq.com/rain/a/20200311A0U7Y500?pc). Accessed May 2021.
[40] Sohu website (http://mt.sohu.com/20160910/n468154602.shtml). Accessed May 2021.

b) As the construction of green spaces lagged behind the urbanization process for a long time (Zhao et al. 2003), Zhengzhou finally lost its reputation as a “Green City”. This largely urged the municipal government to initiate a greening campaign in 1997 and then set the goal of creating a “Landscape Garden City” to improve the city’s appearance.

Urban parks were increased through innovative development approaches led by the municipal government, including changing other types of green land into and renting land owned by farmers for urban parks. Subsequently, as part of a comprehensive renewal of the old city, multiple tools, such as regeneration of run-down areas, replacement of industrial land, and conversion of illegal construction land, were applied to develop urban parks. Furthermore, through the overall urban planning, a large area of parks at multiple levels was developed in the new east urban zone to create an ecological and livable environment (***Figure 4.10***). In addition, Management Measures for Zhengzhou UGS Boundary was published by the municipal government to ensure designated existing and future UGSs. From 1996 to 2012, the area of urban parks grew rapidly, up to about 4.5 times.

The local authority approved the Green Space System Plan for Zhengzhou City (2003-2010) (***Figure 4.9***) and the Green Space Plan for Local Recreation in Zhengzhou Old City. As a result, a large number of residential-level parks were constructed with the consideration of spatial balance.

The belt-shaped parks along Xiong’er River, Dongfeng Canal, and Jinshui River were laid out and open to the public, creating more convenient leisure opportunities. It was the first time that UGSs were defined as a system, and catchment areas of the parks were considered.

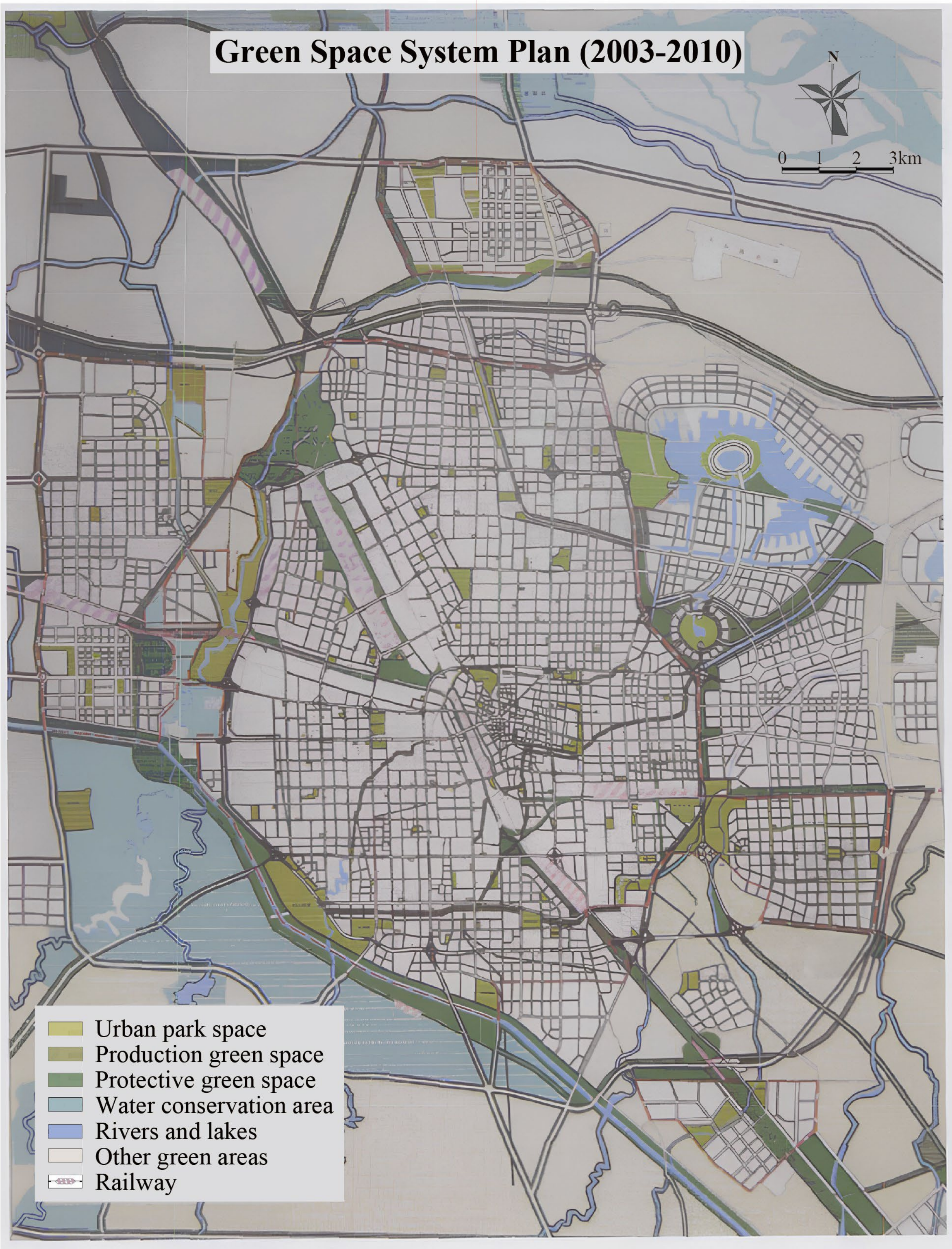

Figure 4.9: Green Space System Plan for Zhengzhou City (2003-2010) (Source: Zhengzhou Landscaping Bureau).

Figure 4.10: The parks in the new east urban zone (Source: Sohu website[41]).

Under the call of the greening campaign, remarkably, most urban parks gradually changed into free-access public parks and gained more visibility from the outside by demolishing park fences. Various functional zones were added to the large parks, such as fitness areas for seniors and children's playgrounds. Due to the broad introduction of flowering plants, flower viewing in urban parks became popular. And urban parks had gradually played a role in attracting visitors during major festivals and events. In general, the uses of urban parks were significantly improved, and the parks' recreational functions were enhanced.

4.1.1.4 The promotion phase (after 2012)

a) Zhengzhou was designated as "National Central City" in 2016 and is at the highest level in the national urban system planning with eight other cities, including Beijing, Tianjin, and Shanghai, which required a higher standard for urban development of Zhengzhou.

b) After realizing the "Landscape Garden City", Zhengzhou took the "Ecological Garden City" as its new development goal and then "Park City" in order to improve the urban living environment.

To strengthen the construction and management of urban greening, the new version of regulations on UGSs in Zhengzhou took effect in 2012. In response to the rapid expansion of urban built-up areas, it emphasized reserving essential land for urban parks in the newly planned urban zones. In addition, the updated regulation clarified that the municipal government was responsible for allocating land for the parks. In order to optimize the distribution of urban parks, along with the continuous comprehensive regeneration of the old city and run-down areas, appropriate plots freed up were encouraged to be used for developing urban parks. Compared with 2012, the area of urban parks more than doubled in 2018.

[41] Sohu website (https://m.sohu.com/a/428818414_789617). Accessed May 2021.

The local authority accepted the Green Space System Plan for Zhengzhou City (2013-2030) (***Figure 4.11***). And the goal of developing an urban park system was put forward. Moreover, the planning and construction of green and ecological corridors along significant circular and radial roads were widely implemented, which has enhanced the link between green spaces. Furthermore, the Three-Year Development Plan for Providing Public Green Spaces within 300 m and Parks within 500 m Ranges was issued by the local authority in 2018, aiming to achieve full coverage of park catchment areas (***Figure 4.12***). Thus, many parks at the municipal, district, and residential levels were planned and constructed step by step to mitigate the uneven distribution. On the whole, the connectivity and spatial balance of urban parks were much emphasized and improved.

In order to enrich the experience of park users, multiple types of parks were developed, including wetland parks and theme parks. Besides, through ecological approaches, such as urban rainwater collection and ecological revetment design, urban parks have been expected to provide ecosystem services. Furthermore, historical and cultural characteristics are valued, aiming to use urban parks to display and transfer urban culture. It can be said that urban parks are not only increasingly improved to meet diverse leisure and recreation demands but also play an essential role in promoting urban ecology and culture.

Figure 4.11: Green Space System Plan for Zhengzhou City (2013-2030) (Source: Zhengzhou Landscaping Bureau).

Figure 4.12: Plan for the Coverage of Park Catchment Area (Source: Zhengzhou Landscaping Bureau).

4.1.2 Developmental trends of urban parks

(1) Multiple implementation approaches

To cope with the weak position of urban park development regarding land availability under the market mechanism, a method combining centralized allocation and legislative control is formed in Zhengzhou. With the acceleration of its urbanization, urban park development has been gradually integrated into the urban regeneration process, relying on land-use change. Besides, other available fragmented land is also encouraged to be flexibly converted to parkland. For newly expanding urban zones of Zhengzhou, urban parks are highly considered from the initial planning.

(2) Systematic and balanced spatial layout

Urban parks in Zhengzhou have been gradually considered as a whole system with a distinct hierarchy. The connectivity of urban parks is strengthened through belt-shaped parks along rivers and roads, which significantly improves accessibility. The spatial distribution of urban parks has undergone a transition from relatively random to balanced. Moreover, the indicators for urban park allocation in Zhengzhou have evolved from controlling baseline (e.g., park area per capita) to assessing accessibility (e.g., park catchment area).

(3) Humanized functions and uses

With the development of Zhengzhou city, special functions (e.g., agricultural production) caused by historical reasons are gradually abandoned. Leisure and recreation have become the main functions of urban parks to meet the needs of citizens. Meanwhile, as urban parks tend to be diversified, urban parks have taken cultural promotion and ecological improvement roles. Moreover, from closed to open, from payment to free, the service scope of urban parks in Zhengzhou has been dramatically expanded.

(4) Sustainability and nature-based solutions

Urban parks, as nature-based solutions, play an increasingly important role in addressing Zhengzhou's emerging urban environmental problems. Their planning and design concept have evolved and enriched, such as planting design, rainwater collection, and ecological revetment design. In response to rapid urbanization and climate change, urban parks have developed a wide range of ecosystem services, including rainwater management, heat island mitigation, biodiversity improvement, etc. Overall, nature-based solutions continue to promote sustainable urban development by enhancing the social well-being and urban health of Zhengzhou.

4.1.3 Discussion on developmental strategies

(1) Innovating land use approaches

As Zhengzhou continues to undergo accelerated urbanization, the availability of land resources in the central urban area tends to decrease. Hence, the solution of simply planning more new land for urban parks will no longer be appropriate for the crowded urban environment. At the same time, the long-term relatively rapid and extensive urban expansion has resulted in unreasonable urban land use patterns. Thus, in order to change the insufficient and unbalanced supply of urban parks, comprehensive and efficient utilization of underutilized land and neglected space can be a promising approach (Ren 2003, Wang et al. 2019). For example, Singapore reserves land for green space by rezoning and integrating low-efficiency land. In addition, for certain types of open spaces (e.g., schoolyards, rooftops, parking, roads, and markets), the application of double-use parks and temporary parks can be realistic solutions to increase park space (Harnik 2010).

(2) Responding to user group needs in a social context

With the development of modern cities, the connotation of public service equity has evolved from spatial equality to social equity (Jiang et al. 2011). Specifically, the concept and measurement standards of urban park equity have shown a more refined trend with the evolution of city level, social demand, and public awareness (He et al. 2019). It can be said that urban parks are expected to have higher adaptability, changing from place-based to people-based measures and from large-unit to small-unit measures. However, the allocation of urban parks in Zhengzhou has been limited to promoting spatial balance, and it is insufficient to deal with diverse user needs and uneven social context. Considering the developmental phase of urban parks, it is necessary to pay attention to diversified needs of user groups within the complex social context in order to balance the supply and demand of urban parks.

(3) Improving public participation mechanism

Various findings have proven that public participation is an integral part of sustainable urban park planning and management (Anuar et al. 2018, Huang 2010, Speller et al. 2005). On the one hand, public participation helps to understand park users' demands and integrate their ideas to improve the projects. On the other hand, involving local inhabitants in different stages of park development can significantly enhance their sense of responsibility for the active maintenance of urban parks (Yan 2019). However, top-down planning and management have long been in operation for urban parks in Zhengzhou, which gives local citizens few opportunities to influence decision-making. Therefore, to achieve more effective development, the authorities should support and ensure public participation, including providing diversified channels for communication and ensuring the transparency of the decision-making process.

4.1.4 Summary

The sequential views, the place and its spirit, and the content altogether define urban parks, open spaces and streetscapes, as an integral part of urban design, is the art of relationship (Cullen 1971). The duty is therefore to explore new, hidden relationships or strengthen existing ones, which provide both healthy recreation and leisure, and visual urban experience, unveiling the values and characteristics of the specific place to the spectator.

I selected Zhengzhou as the empirical case in urban China and reviewed its urban park development. The results show that the urban park development in Zhengzhou is a continuous and changing process. It has gone through four progressive phases: the emergence phase (1949-1977), the growth phase (1978-1996), the acceleration phase (1997-2012), and the promotion phase (after 2012). On the whole, we can see an evolution in Zhengzhou's urban parks in terms of diversification of implementation approaches, systematization and balance of spatial layout, humanization of functions and uses, and sustainability and nature-based solutions. The future developmental strategies to tackle existing problems mainly lie in innovative land-use approaches, response to user group needs in a social context, and improvement of public participation mechanisms. The research findings may help formulate adaptive and effective policies and planning tools for urban parks and provide a basis for further research on urban parks and Zhengzhou's road to the ideal "Park City".

4.2 Spatial patterns of accessibility and equity in Zhengzhou's UPPs

To illustrate the spatial patterns of accessibility and equity in Zhengzhou's UPPs, I focus on three specific questions in this study: **a)** How to effectively measure spatial accessibility and assess distributional equity in urban parks? **b)** What are the characteristics and causes of accessibility distribution both at the neighborhood scale and the urban ring scale in Zhengzhou? **c)** What corresponding solutions can be formulated to mitigate spatial disparities? First, this study applies an improved 2SFCA method to measure park accessibility, combining park quality with size and category to comprehensively describe park supply, and considering selection probability of residents among multiple available parks. Additionally, residents' demand is refined by population estimation for neighborhood-scale units. In addition, the measurement of travel cost is improved by applying real-time navigation data. Second, park accessibility is analyzed spatially and statistically both at the neighborhood scale and urban ring scale, so that the characteristics of accessibility distribution can be examined. Lastly, by using K-means cluster analysis, I reveal the accessibility patterns as well as causes behind the spatial accessibility differences. Accordingly, targeted improvement decisions can be made. The findings of this study could serve as a tool for identifying areas of urban park shortage and how they differ from other areas, which can guide urban planning and landscape design to address specific inequities. The research framework is shown in ***Figure 4.13***.

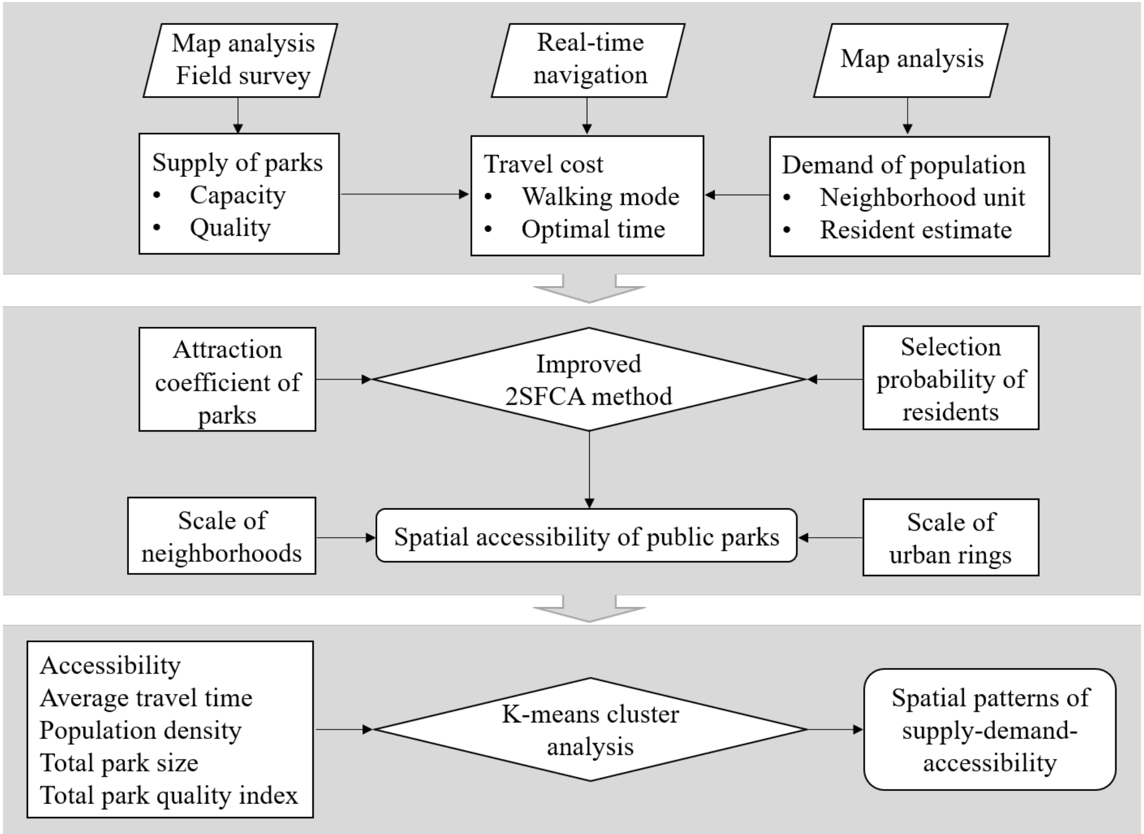

Figure 4.13: Research framework for accessibility analysis and equity evaluation of urban parks (Source: Author).

4.2.1 Spatial accessibility based on improved 2SFCA method

Statistical analysis indicated significant differences in accessibility distribution among neighborhoods (***Table 4.1***), with a mean of 0.038 and a standard deviation of 0.119. A total of 82.18% of the neighborhoods have lower accessibility than the city average. Additionally, the proportion of underserved neighborhoods (<0.01) is significantly high, with a value of about 32.78%.

Table 4.1: Statistical analysis of neighborhood accessibility (Source: Author).

	Mean	**Standard deviation**	**Below-average neighborhoods**	**Underserved neighborhoods**
Accessibility	0.038	0.119	82.18%	32.78%

Note: The underserved neighborhoods are defined as those with an accessibility value below 0.01.

The graphs (***Figure 4.14***) show that the park accessibility of each ring is obviously different, and thus it is a demonstration of unfairness. From the city center to the city fringe, both the average accessibility and the standard deviation of neighborhoods increases. The inner rings have lower average accessibility due to dense population and relatively insufficient parks. The outer rings have a higher standard deviation of accessibility, which is related to the imbalanced distribution of parks. In terms of neighborhoods with below-average accessibility, the inner rings have a significantly higher share than the outer rings, aligning with the change in the mean. Conversely, the outer rings have an apparently higher percentage of underserved neighborhoods than the inner rings, which is also consistent with the change in standard deviation.

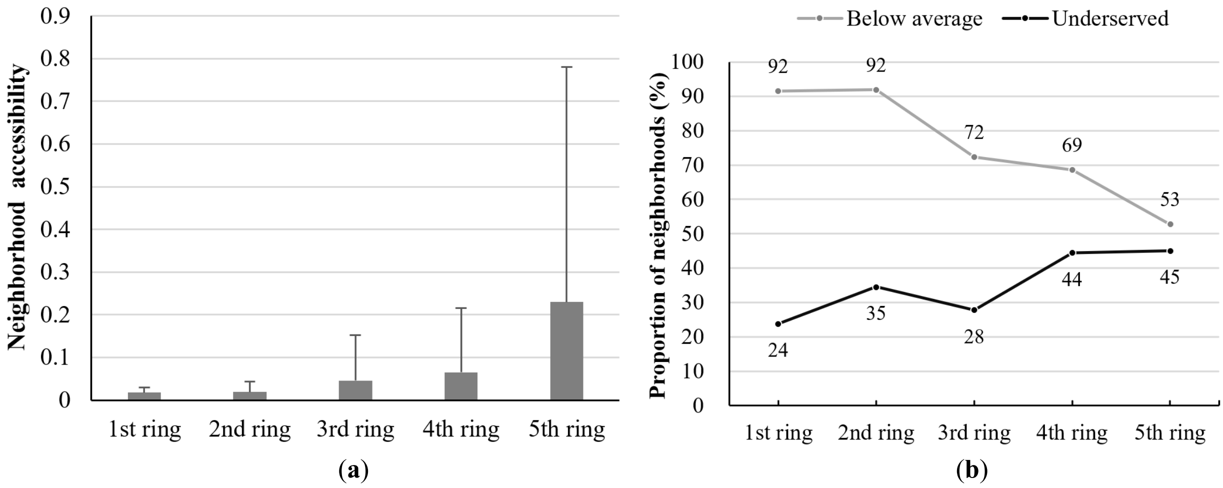

Figure 4.14: Statistical analysis across urban rings: (a) neighborhood accessibility; (b) proportion of below-average and underserved neighborhoods. Error bars indicate standard deviation (Source: Author).

According to the classification of the geometric interval method, the accessibility value of the overall neighborhoods was grouped into six grades (***Figure 4.15***). Overall, the map highlights that park accessibility is not equally distributed across the city. The areas with high accessibility are relatively agglomerated around large lakes and major rivers due to a few large waterfront parks such as Xiliu Lake Park and Dongfeng Canal Park. Several neighborhoods with extremely low accessibility are primarily distributed in the southwest of the first ring, the south and east of the second ring, the west of the third ring, and the north of the fourth ring, where parks are generally lacking and far from large and high-quality parks. Additionally, there is an apparent linear extension trend of low accessibility from northwest to southeast within the third ring road affected by the main railway line. Since areas along the railway line has been dominated by industrial and warehouse land in the historical development of the city, there are few urban parks planned around. As the population increased during urbanization, residential land expanded along the railway line, yet away from parks.

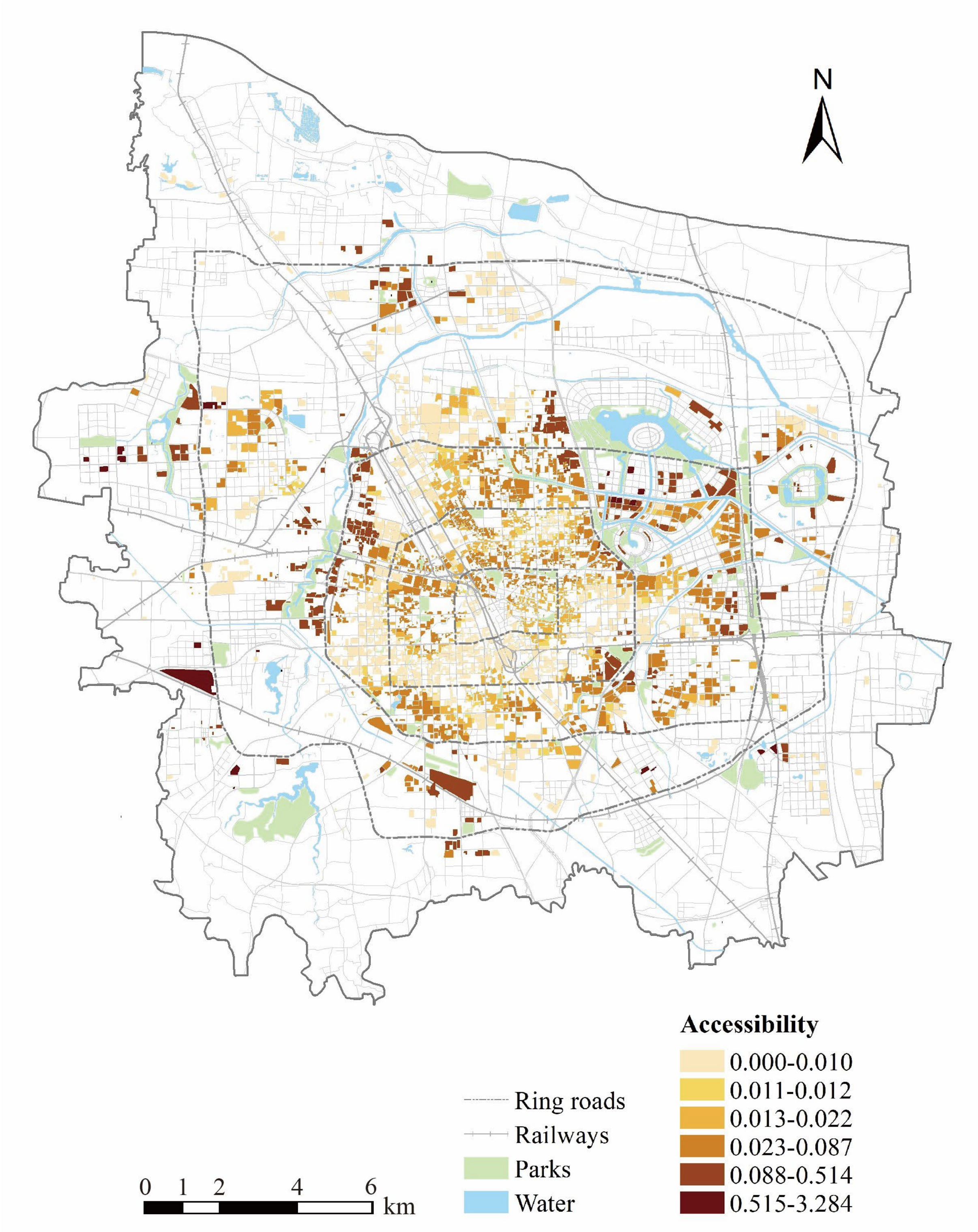

Figure 4.15: Spatial distribution of park accessibility value (Source: Author).

4.2.2 Equity evaluation based on K-means cluster analysis

K-means cluster analysis was performed on 4030 neighborhoods after deducting neighborhoods with no data and extremely high accessibility. I identified the optimal clusters of four accessibility types based on five major factors (accessibility, average travel time, population density, total park size, and total park quality index). ***Table 4.2*** shows the final cluster centers. By comparing the mean values of each factor of the clusters, typical attributes of each accessibility type and the way these types differ from each other were revealed. Each cluster was named separately for factor characteristics (high, medium, or low) in terms of supply, demand, and accessibility.

Table 4.2: Final cluster centers (Source: Author).

	HMM	LML	HLH	MHL
Neighborhood (numbers)	997	2494	228	311
Population ratio (%)	20%	56%	11%	13%
Accessibility	−0.00866	−0.25272	3.0144	−0.15549
Average travel time	−0.1629	0.11978	−0.41835	−0.13161
Population density	−0.20521	−0.18257	−0.34133	2.3722
Total park size	0.39058	−0.42391	3.03554	−0.07804
Total park quality index	1.19771	−0.46355	−0.15096	−0.01162

Note: Except for the number of neighborhoods and population ratios, the above data were transformed to standard normal distribution by means of Z-score normalization.

The distinguished accessibility regions were mapped in ***Figure 4.16***, revealing accessibility patterns across the city. Overall, there is a mismatch between park supply and population demand in Zhengzhou. This mismatch is evident in two ways: either the supply level exceeds the demand level, which includes high-supply medium-demand medium-accessibility (HMM) and high-supply low-demand high-accessibility (HLH); or supply level falls short of the demand level, which includes low-supply medium-demand low-accessibility type (LML) and medium-supply high-demand low-accessibility (MHL). The HMM type is mainly distributed within the third ring, comprising 997 neighborhoods and 20% of the population. The total park quality index of these neighborhoods is the highest due to their proximity to urban comprehensive parks and theme parks in good conditions. However, the supply of total park size is relatively not high, so the accessibility level is moderate. The LML type is primarily located within the fourth ring. This cluster has most neighborhoods (2494) and population (56%) of all the clusters. However, both total park size and total park quality index in cluster LML are the lowest, and the average travel time is the longest. Consequently, these neighborhoods have the lowest accessibility among the four categories. The HLH type is mostly situated around city lakes both in the eastern and western areas of the city. This is the smallest group, with only 228 neighborhoods and 11% of the population. It has the lowest population density but the highest total park size. And the average travel time is the shortest, so the accessibility is the highest of all the clusters. Due to proximity to large waterfront parks, these neighborhoods have become livable places on the periphery of the central urban area. The MHL type is spread across the city, with 311 neighborhoods and 13% of the population. These neighborhoods have the highest population density. In contrast, the supply of total park size and quality is relatively insufficient, thus the corresponding level of accessibility is low.

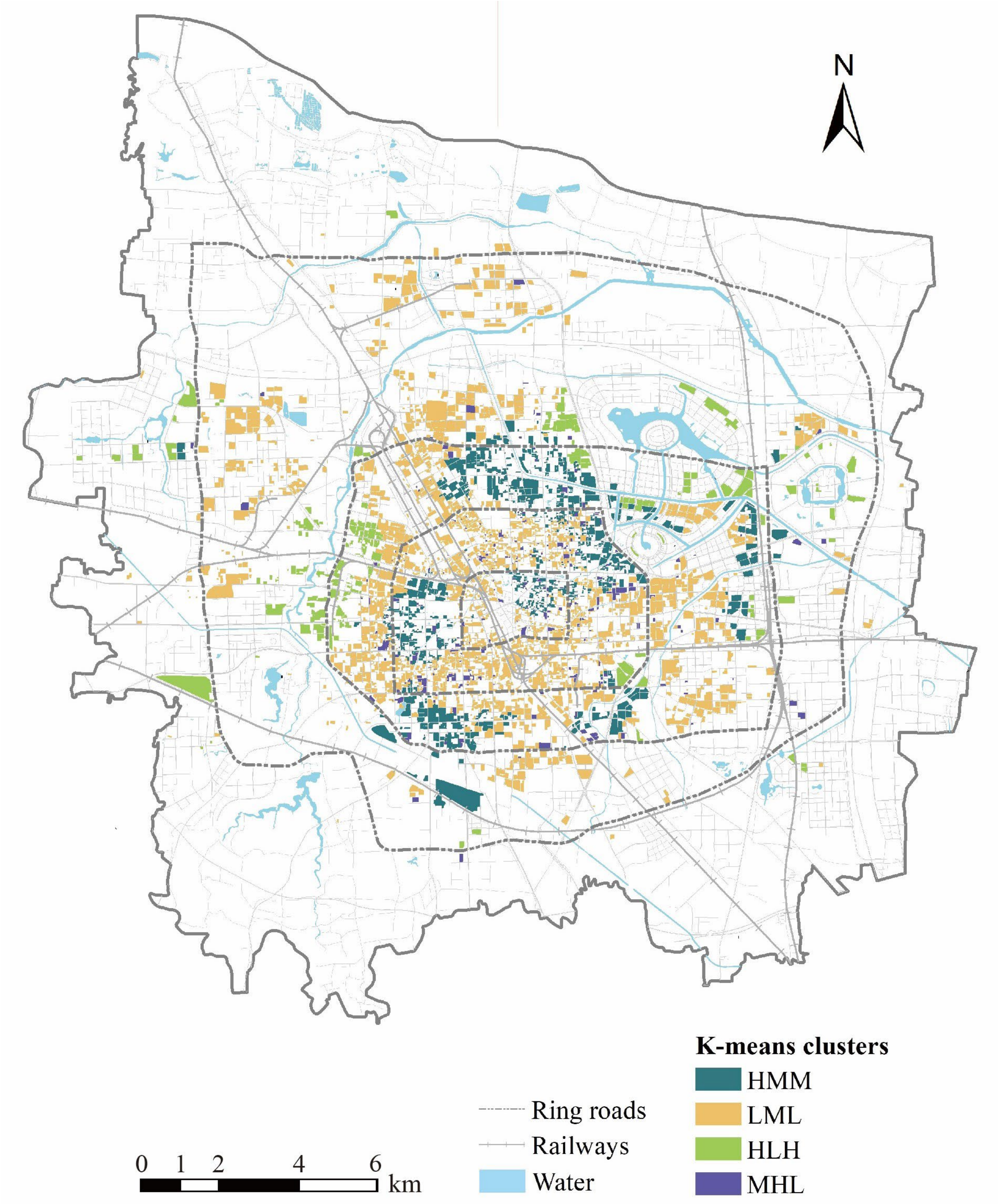

Figure 4.16: Neighborhood clusters in terms of supply, demand, and accessibility (based on accessibility, average travel time, population density, total park size, and total park quality index) (Source: Author).

The graph (***Figure 4.17***) shows that the spatial distribution of accessibility types has both similarities and differences between urban rings. The inner two rings exhibit a similar quantitative distribution of accessibility types. Both regions have the highest proportion of neighborhoods in the LML and HMM types, followed by MHL, with very few neighborhoods in cluster HLH. In contrast, the outer two rings show a different quantitative distribution of accessibility types. Both regions have the highest proportion of neighborhoods in the LML and HLH types, followed by a small proportion of HMM and MHL. From the city center to the city fringe, cluster HLH starts to emerge from the third ring outward. In contrast to the inner two rings, this shift can be attributed to the presence of some large parks near areas with low population density in the outer rings. Overall, the LML type is the most widely distributed, with more than half of the neighborhoods in each ring. This indicates that the low accessibility of neighborhoods within each ring is mainly affected by park supply shortages. The second-highest proportion of neighborhoods is the HMM type in the inner rings, and the HLH type in the outer rings. Both clusters exhibit a high supply of parks, but this is attributable to different factors: the inner rings have a high total park quality index, whereas the outer rings have a high total park size. This suggests that for neighborhoods with a high supply of parks, the outer rings have higher accessibility mainly due to a lower demand than in the inner rings. In addition, the proportion of neighborhoods in the MHL type showed an overall decreasing trend from the city center to the city fringe. This shows that, compared to the outer rings, the inner rings have more low-accessibility neighborhoods because of the high demand.

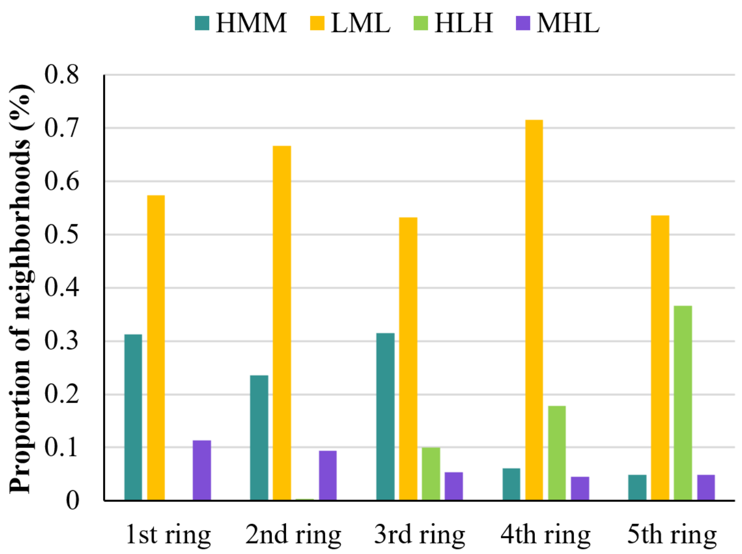

Figure 4.17: Statistical analysis across urban rings of the proportion of four accessibility types of neighborhoods (Source: Author).

4.2.3 Discussion on solutions and limitations

The inequitable spatial patterns of park accessibility across urban rings in Zhengzhou can be attributed to the city's various stages of urbanization and park development. Initially, during the early stages of urban development, insufficient attention was given to the creation of green spaces within the inner two rings. Subsequently, as urban regeneration progressed, park quality improved, but increases in park area often remained at a relative disadvantage due to economically-driven land development (Yang et al. 2021). Consequently, as urbanization progressed and populations increased, the shortage of park spaces intensified. This resulted in lower average accessibility and a significantly higher proportion of neighborhoods with below-average accessibility in the inner rings compared to the outer rings. This also explains why the inner two rings have the highest proportion of neighborhoods in the LML and HMM types, but very few neighborhoods in the HLH cluster. However, as Zhengzhou's socio-economic conditions and environmental concerns improved, urban planning began to emphasize the creation of an ecological and livable urban environment. With ongoing urbanization, built-up areas expanded outward. Comprehensive planning in the outer rings led to the development of extensive park areas, which, coupled with lower population densities, resulted in higher average accessibility and a lower proportion of neighborhoods with below-average accessibility than in the inner rings. Nonetheless, the planning goals of transforming Zhengzhou into a "Landscape Garden City", particularly in the new east urban zone (Yang et al. 2021), favored the aesthetics and monumental grandeur of the urban landscape over equitable park distribution. This approach led to the centralized allocation of large-scale, high-quality parks, explaining the presence of cluster HLH in the outer rings. Additionally, the uneven spatial distribution caused higher standard deviations of neighborhood accessibility as well as a higher proportion of underserved neighborhoods compared to the inner two rings. This disparity aligns with the observation that the outer rings have a higher proportion of underserved neighborhoods, illustrating the complex interplay between urban planning, socio-economic development, and the distributional equity of parks in Zhengzhou.

The results reveal, both spatially and statistically, that the access to parks in Zhengzhou is generally unevenly distributed among neighborhoods and between urban rings. Additionally, the cluster analysis identified four types of neighborhoods as well as causes behind the spatial accessibility differences. Specific to different types of regions, the following solutions may help reduce spatial disparity in urban park accessibility. First, for neighborhoods in the LML and MHL clusters, parks should be increased or expanded. In crowded built environments, such as the inner two rings, underused and neglected land can be efficiently repurposed to create pocket parks, thereby reducing travel time for residents (Yang et al. 2021). Second, in densely populated areas, the limited opening of nearby high-quality green enclosures or the application of dual-use parks on certain types of open spaces (such as schoolyards and rooftops) can effectively balance the park supply and resident demand (Harnik 2010). Third, since the quality of a park can significantly impact visitor numbers (Hughey et al. 2016, McCormack et al. 2010, Rigolon 2016), unpopular parks within or near the LML and MHL clusters should be improved by involving community members in the park development process. This includes renovation and management efforts, (Yang et al. 2021), such as increasing the diversity of facilities and amenities, enhancing the appeal of landscape features, and paying attention to maintenance. Fourth, in the LML and MHL clusters with higher travel time, road connectivity between parks and surrounding neighborhoods can be improved by increasing sidewalk density and adding entrances to large parks. Specifically, better connections over the railway axes could facilitate improved park accessibility. Finally, in the HLH cluster, characterized by an excess park supply and low population demand, residential area planning should be integrated with urban park allocation. This approach will optimize resource allocation by managing land use patterns around parks, ensuring that parks can fully serve nearby residents.

This research has several limitations that may be addressed in the future. First, it uses a unified indicator system to characterize park attractiveness to the whole population, regardless of the visitor preferences of different groups in terms of park quality and type. With the help of a detailed social survey, a pre-analysis of residents' park usage behavior and opinions of various groups can better reflect their subjective needs for parks. Second, numerous studies have shown that the distribution of urban parks tends to differ between different social groups (Dai 2011, Rigolon 2016, Rigolon et al. 2018, Zhang et al. 2022). Therefore, combined with detailed demographic data, comparative studies of park accessibility across age or income groups can be conducted to reveal underserved groups and then develop proper strategies to achieve social equity in parks. Third, transit to parks by other modes, including public transport and personal cars, was not considered, while several related studies have confirmed different results (Tong et al. 2021, Xing et al. 2020b, Yang et al. 2020). Additionally, with the exception of walking in the walkable concept, access to parks on bicycles, skates, etc., may be appreciated, but was rarely discussed, which can be incorporated into studies to match the specific situation of park visits in different cities. Finally, based on survey data or urban big data, such as mobile phone data and social media data, of residents' actual park visits, the match between calculated accessibility and actual access can be measured to further verify the accuracy of my accessibility evaluation.

4.2.4 Summary

In this study, an attempt was made to establish a comprehensive and systematic procedure for urban park accessibility analysis and equity evaluation by applying a supply-demand improved 2SFCA method and K-means cluster analysis, based on multi-source data. Accordingly, I conducted a case study at the neighborhood scale and urban ring scale in the central urban area of Zhengzhou. The results show that access to parks is not equitable among neighborhoods across the city. In addition, the mean and standard deviation of accessibility both show an increasing trend from the center to the periphery. All the neighborhoods are broadly clustered into four accessibility types, each with different characteristics and causes. The spatial distribution of accessibility types has both similarities and differences between urban rings. An equity study on park accessibility could guide decision makers and urban planners to target underserved neighborhoods and formulate effective policies and strategies aimed at urban park equity.

5 NEW SCIENTIFIC RESULTS

The new scientific findings from the present dissertation results are summarized in the following theses:

Thesis 1: I synthesized the basic historical development of UPPs with regard to their origins and publicness development worldwide.

UPPs have emerged and developed in response to the needs of urban life and as solutions to unique urban problems across various developmental contexts. Examining the origins and development of UPPs can provide valuable insights into their roles, functions, and planning strategies, which are tailored to address the opportunities and challenges inherent in contemporary urban settings.

Two roots of urban parks within cities in history are traced. One is private open spaces, including royal gardens and noble gardens, typically reserved for the privileged class and not accessible to the general public. The other is public open spaces, encompassing natural scenic areas, open spaces associated with religious activities, and other open spaces designated for specific public purposes, primarily serving special functions with corresponding design or offering limited public service benefits. The development of publicness in urban parks can be categorized into three main stages. Initially, the so-called “public parks” originated during the 17th century with the transformation of royal and noble gardens into spaces accessible to the public, albeit with restricted access. In continental Europe, the early public gardens traced back to at least the late 18th century, rooted in the tradition of setting aside green spaces for public use, though the practice was largely permissive and unorganized. Modern public parks, as recognized today, emerged in the mid-19th century during a period marked by industrialization and urbanization. These parks, laid out and managed by public institutions, were freely accessible to people of all social classes and incorporated integrated park planning.

Thesis 2: I identified the advances in distributional equity assessment of UPPs, considering the context, content, and characteristics across different developmental stages.

Given the inherent complexity of the concept of distributional equity, despite its central role in UPP planning and assessment, there exists a dearth of integrated analyses regarding the development of connotations and criteria associated with distributional equity. Across different developmental stages, assessing the equity of park distribution demonstrates cognitive distinctions and differs significantly in planning objectives and equity principles.

Drawing on the developmental characteristics of societal context and corresponding public values advocated, this study argues that the distributional equity assessment in UPPs has undergone four main modes: territorial equality, locational fairness, group justice, and social equity. Within the paradigm of traditional public administration, characterized by a focus on efficiency, territorial equality prioritizes equal share weight in different territories. It strives for spatial guarantee and aligns with the welfare-based principle. Subsequently, within the framework of new public management, marked by an emphasis on effectiveness, locational fairness underscores fair opportunity of homogeneous persons. It pursues spatial balance and adheres to the egalitarianism-based principle. In contrast, in the context of civil rights movement, characterized by its emphasis on justice, group justice focuses on just availability for disadvantaged groups. It seeks socio-spatial matching and follows the need-based principle. More recently, within the framework of new public service, distinguished by its emphasis on democracy, social equity concentrates on equitable benefit to groups of individuals. It aspires to socio-spatial satisfaction and adheres to the demand-based principle. The advances are closely linked to the development of urbanization and the construction of urban parks.

Thesis 3: I highlighted the developmental characteristics of four distributional equity models in the assessment subjects and measurement criteria.

In the assessment of UPP allocation and delivery, four primary models for distributional equity have been identified, each demonstrating significant distinctions in terms of planning objectives and equity principles. Accordingly, there has been a discernible shift in the assessment subjects and measurement criteria associated with the level of urbanization, the degree of urban construction, and the corresponding mode of park development.

During the early and accelerated phases of urbanization, within the context of large-scale underway construction of modern urban functions and spatial systems, urban parks exhibit an extensive development mode. Park resource allocation is approached from a “place-based” and “consequence-oriented” perspective. In the phase characterized by the fundamental completion and self-enhancement of urbanization in developed regions, the development of urban parks manifests a refined mode, emphasizing the micro-renewal and governance of urban space. Park service delivery is directed by a “people-based” and “rule-oriented” perspective. However, the development of the concept of distributional equity in UPPs is not characterized by the mutual substitution of old and new ideas. Instead, it unfolds in conjunction with the support of urban construction development, gradually expanding in tandem with the progression of public value governance. Specifically, the aspirations for distributional equity at each stage typically built on the accomplishment of objectives of distributional equity from the preceding stage. The inadequacies in the cognition of distributional equity at each stage usually function as a prerequisite for deepening the conceptualization of distributional equity in the subsequent stage.

Thesis 4: I recognized the transformations of four distributional equity models in measurement between parks and residents, as well as the relationships of these models with contextual equity and procedural equity.

The measurement of park distribution has progressed incrementally, shifting from a primary emphasis on physical space to an exploration of the dynamic interplay between space and society. The relationship between distributional equity and the other two dimensions of the equity framework depends on how distributional equity is understood and how its concepts are applied to planning proposals.

Based on quantified spatial relationships, the assessment of territorial equality and locational fairness focuses on the question: “Where and how many resources are provided?”. Consequently, the associated metrics highlight the resource quantity and spatial location of parks. Through spatial statistics and analysis method, indicators such as resource density or place opportunity are employed to analyze the park distribution patterns. Territorial equality and locational fairness implement one-size-fits-all solutions without considering the differentiation of social spaces and the stratification of social groups. Clearly, contextual equity and procedural equity are not necessary to achieve either of these narrowly defined types of distributional equity. In terms of group justice and social equity, premised on a broader and deeper intersection between parks and residents, this assessment explores the question of “Who receives what kind of services?”. As a result, the associated metrics assess the service quality and benefit output for residents. Through socio-spatial survey and evaluation method, indicators of group availability and service performance are used to systematically measure the distributional equity. Group justice and social equity require solutions tailored to specific needs of social groups or diverse demands of individuals. In this context, procedural equity is necessary to guarantee that the mechanisms governing park allocation are just and inclusive, while contextual equity ensures that distributional equity is achieved in a meaningful and targeted way.

Thesis 5: I identified the distinctive characteristics of five primary accessibility measures for urban parks and highlighted the advantages of the 2SFCA method through a detailed analysis of their conceptual differentiation.

The varied conceptualization and operationalization of spatial accessibility have given rise to diverse measurement methods. The efficacy of specific accessibility measures in reflecting the essence of equity models and guiding planning orientations depends on the specific interpretation of the accessibility concept and the precise specification of these measures.

There are five primary accessibility measures for urban parks: container method, buffer method, distance-cost method, cumulative-opportunity method, and gravity-based method. Each of these methods exhibits respective properties, with distinct strengths and limitations at both theoretical and practical levels. Conceptual differentiation among these measurement methods is primarily grounded in four key components: spatial reference, measurement attributes, integration mechanism, and decision making. Upon comparison, it is evident that the gravity-based method appears to be a more effective measure. This is attributed to its ability to comprehensively articulate differences across various aspects, including the spatial distribution of parks and residents, travel impedance, park attractiveness, and resident population. As a special case of the gravity-based method, the 2SFCA model incorporates the advantages of both cumulative-opportunity method and buffer method. This integration enables it to consider effective travel distances by imposing a distance threshold. Consequently, it has emerged as one of the most employed and developed accessibility measure, with a range of extensions to the classic 2SFCA model.

Thesis 6: I proposed an improved 2SFCA method for measuring urban park accessibility through model optimization and data refinement.

The improved accessibility method integrates the actual factors affecting residents' access to urban parks including park quality and park competition. Compared to the classic 2SFCA model, this improved method enhances the accuracy of measuring urban park accessibility regarding park supply, population demand, and travel cost utilizing multi-source data.

A supply-demand improved 2SFCA method was developed to evaluate spatial accessibility and equity, particularly introducing the attraction coefficient of parks and selection probability of residents. Specifically, for the study, the attraction coefficient of parks combined the park size, category and quality based on efficient big data and on-site investigation data. Selection probability of residents among multiple available parks was quantified by combining the park attractiveness and travel impedance. This was applied as selection weights to both steps of the model to fit possible supply and demand relationship. In terms of the demand, the population of the neighborhood-scale unit was estimated based on residential building attributes (including footprint area and floors) derived from map service platform, rather than rough administrative unit demographics. Additionally, travel time instead of travel distance was used to measure travel cost based on real-time navigation data, which can more accurately reflect the actual travel situation of residents and is relatively more convenient than traditional data collection. Overall, the accuracy of the park accessibility measurement has been improved in terms of both the model and data.

Thesis 7: I established a comprehensive and systematic procedure for accessibility analysis and equity assessment of urban parks.

Most of the literature on equity has emphasized the identification of distributional disparity and underserved areas within the study area, while failing to examine the causes behind the spatial differences. An attempt was made to establish a comprehensive and systematic procedure for urban park accessibility analysis and equity assessment by applying a supply-demand improved 2SFCA method and K-means cluster analysis.

Spatial accessibility of urban parks was firstly measured by an improved 2SFCA method with comprehensive consideration of supply and demand. Then, to advance systematic equity research and targeted strategy development, the spatial patterns, differences, and causes of park accessibility were further examined by K-means cluster analysis. By clustering the results of five main factors (accessibility, average travel time, population density, total park size, and total park quality index), I got integrated spatial patterns of supply, demand, and accessibility for neighborhoods. The findings of this study could serve as a tool for identifying areas of urban park shortage and how they differ from other areas, which can guide urban planning and landscape design to address specific inequities. This study also illustrated the feasibility and limitations of the research framework for park accessibility and equity assessment in the central urban area of Zhengzhou, which can be flexibly applied to other cities with the use of appropriate data following the approach.

Thesis 8: I provided a comprehensive overview of the developmental phases and trends of UPPs in Zhengzhou, introducing developmental strategies aimed at tackle existing problems.

Empirical analysis of urban park development from a historical and local point of view is the basis for further research into urban parks. According to the periods of urban development and the opportunities for green space development, a qualitative and inductive review of the evolution processes and trends of urban parks in Zhengzhou from the perspective of implementation approaches, spatial layout, functions and uses is conducted. Following this, development issues and strategies were discussed.

The results show that the urban park development in Zhengzhou is a continuous and changing process. It has gone through four progressive phases: the emergence phase (1949-1977), the growth phase (1978-1996), the acceleration phase (1997-2012), and the promotion phase (after 2012). Overall, an evolution of Zhengzhou's urban parks is evident in terms of diversification of implementation approaches, systematization and balance of spatial layout, humanization of functions and uses, and sustainability of nature-based solutions. The future developmental strategies to tackle existing problems mainly lie in innovative land-use approaches, response to user group needs in a social context, and improvement of public participation mechanisms. The findings may help formulate adaptive and effective policies and planning tools for urban parks.

Thesis 9: I illustrated spatial patterns of accessibility and equity in UPPs at multiple urban scales in Zhengzhou, formulating corresponding solutions aimed at mitigating the spatial disparities.

Empirical evidence of distributional equity in UPPs in rapidly urbanizing regions is important and necessary. By applying an improved 2SFCA method and K-means cluster analysis, based on the application of multi-source data, an equity study on urban park accessibility at the neighborhood scale and urban ring scale was conducted in the central urban area of Zhengzhou. Corresponding solutions were proposed to improve existing situation of accessibility and equity in urban parks.

The results suggest that the spatial access to parks in Zhengzhou is generally unevenly distributed among neighborhoods, and both the mean and standard deviation of accessibility show an increase from the center to the periphery. The cluster analysis reveals a set of four types of neighborhoods: HMM, LML, HLH, and MHL, each with different characteristics and causes. The spatial distribution of the accessibility types exhibits both similarities and differences between the urban rings. Specific to different types of regions, the following solutions encompassing five dimensions may help reduce spatial disparity in urban park accessibility: (1) Increase parks or expand existing parks; (2) limited opening or innovative application of certain types of open spaces; (3) improve unpopular parks through renovation and management; (4) improve road connectivity between parks and surrounding neighborhoods; (5) integrate residential area planning and urban park allocation. The findings could guide decision makers and urban planners to target underserved neighborhoods and formulate effective policies and strategies aimed at urban park equity.

6 CONCLUSION AND PROSPECTS

6.1 Summary of the dissertation

UPPs are widely acknowledged for their multifaceted social, environmental, and economic advantages. Consequently, the Chinese national government champions the “Park City” concept, and within European environmental strategies, urban parks are regarded as essential “nature-based solutions”. However, disparities in access to park benefits within urban areas have led to a growing concern about the distributional equity of UPPs. This issue is increasingly emphasized in the context of urban regeneration and is crucial for advancing ecological civilization and social sustainability.

This dissertation aims to synthesize the basic historical development of UPPs worldwide and in China and to explore the assessment and measurement of equity in their distribution, specifically through the lens of UPPs in Zhengzhou, China. Employing a combination of theoretical and empirical research methodologies, this research presents significant historical developments, theoretical advancements, and empirical insights relevant to UPP development and distributional equity.

(1) The research first provides a detailed synthesis of the historical development of UPPs, encompassing their origins and the development of publicness worldwide, alongside the developmental phases of Chinese urban parks.

   a) The study traces the origins of urban parks, distinguishing between private open spaces like royal and noble gardens, and various types of public open spaces. The publicness development of parks has been recognized in three stages: so-called “public parks” during the 17th century, early public gardens from the late 18th century, and modern public parks post-mid-19th century. For China specifically, the study investigates the earliest categories of urban parks within unique societal contexts and outlines the distinct phases of park development since the mid-20th century, driven by significant national policies. This historical context provides a foundation for understanding contemporary park allocations.

(2) The research then develops a theoretical framework for assessing and measuring equity in UPP distribution, including the advances in distributional equity assessment, a review of spatial accessibility measurement, and a supply-demand improvement of the 2SFCA method.

   a) The study identifies four main modes of distributional equity assessment in UPPs: territorial equality, locational fairness, group justice, and social equity, each with distinct planning objectives and equity principles. These models fall into two types, differentiated by their assessment subjects and measurement criteria, metrics between parks and residents, and their relationships with contextual and procedural equity. It deepens the understanding of connotations and criteria associated with distributional equity.

b) The study systematically reviews primary park accessibility measures: container method, buffer method, distance-cost method, cumulative-opportunity method, and gravity-based method. The conceptual comparison underscores the efficacy of the gravity-based method, especially the 2SFCA model. The study further improves the 2SFCA model by incorporating the attraction coefficient of parks and the selection probability of residents, enhancing the accuracy of accessibility assessment based on multi-source data.

(3) The research finally conducts an empirical analysis of UPPs in Zhengzhou, examining their developmental process and characteristics, as well as the spatial patterns of accessibility and equity.

a) According to periods of urban development and opportunities for green space development, the study identifies four phases of urban park development from emergence to growth, acceleration, and promotion. It also highlights trends in the evolution of urban parks from various perspectives and proposes appropriate strategies to enhance their development.

b) Utilizing an improved 2SFCA method and K-means cluster analysis, based on the application of multi-source data, the study reveals uneven distribution of park accessibility across both the neighborhood and urban ring scales. It identifies various accessibility types and regions and offers practical recommendations for more equitable park distribution.

The findings significantly enhance our understanding of distributional equity in UPPs and offer practical insights for urban planners and policymakers. By addressing inequitable distribution of urban parks, this research meets the critical needs of urban populations. Furthermore, it contributes to the broader discourse on sustainable urban development, providing a foundation for future strategies aimed at achieving equity in urban park planning.

6.2 Recommendations for future research

Distributional equity in UPPs represents a complex and comprehensive concern that combines public value judgment and socio-spatial behavior analysis, rather than merely a holistic assessment of park attributes such as park size, location, and quality. This dissertation endeavors to explore the assessment and measurement of equity in the distribution of UPPs, employing both theoretical and empirical approaches. Nevertheless, it acknowledges existing shortcomings and proposes recommendations for further exploration and enhancement.

(1) There is a deficiency in the empirical assessment of distributional equity for UPPs from "people-based" and "rule-oriented" perspective.

Due to the limitations in gathering data on the social attributes of various groups and their demand characteristics for urban parks, this dissertation did not perform an empirical assessment of distributional equity through the lens of group justice or social equity. The advent of advanced digital technologies, such as urban big data and PPGIS, facilitates a more detailed analysis of socio-spatial data on an individual basis, offering advantages in terms of cost, scale, and efficiency over traditional survey methods. The future extensive utilization of these tools is anticipated to significantly mitigate current limitations. Certainly, it is crucial to recognize that the perspective of distributional equity assessment and the formulation of appropriate measurement metrics must be tailored to the developmental stage of the urban area and its specific socio-cultural context. Accordingly, the assessment of distributional equity is expected to provide targeted park planning guidance.

(2) The spatio-temporal dynamics and evolutionary mechanisms underlying distributional equity in UPPs necessitate further research.

This dissertation conducts a cross-sectional analysis, comparing park accessibility across various spatial units. It focuses on the static spatial pattern of accessibility and equity in UPPs, rather than investigating the dynamics of the pattern. Therefore, it doesn't consider the changes in accessibility and equity patterns and fails to address how these changes are influenced by both spatial and social gradients. Future research should undertake spatio-temporal analysis of the spatial patterns of accessibility and equity in UPPs to identify the dynamic process and characteristics of their distributional equity. This would allow for a deeper exploration of the factors and forces contributing to disparities in existing park accessibility. With a comprehensive understanding of the evolutionary mechanisms shaping the spatial patterns of accessibility and equity, it will be possible to devise adaptive optimization strategies for park planning.

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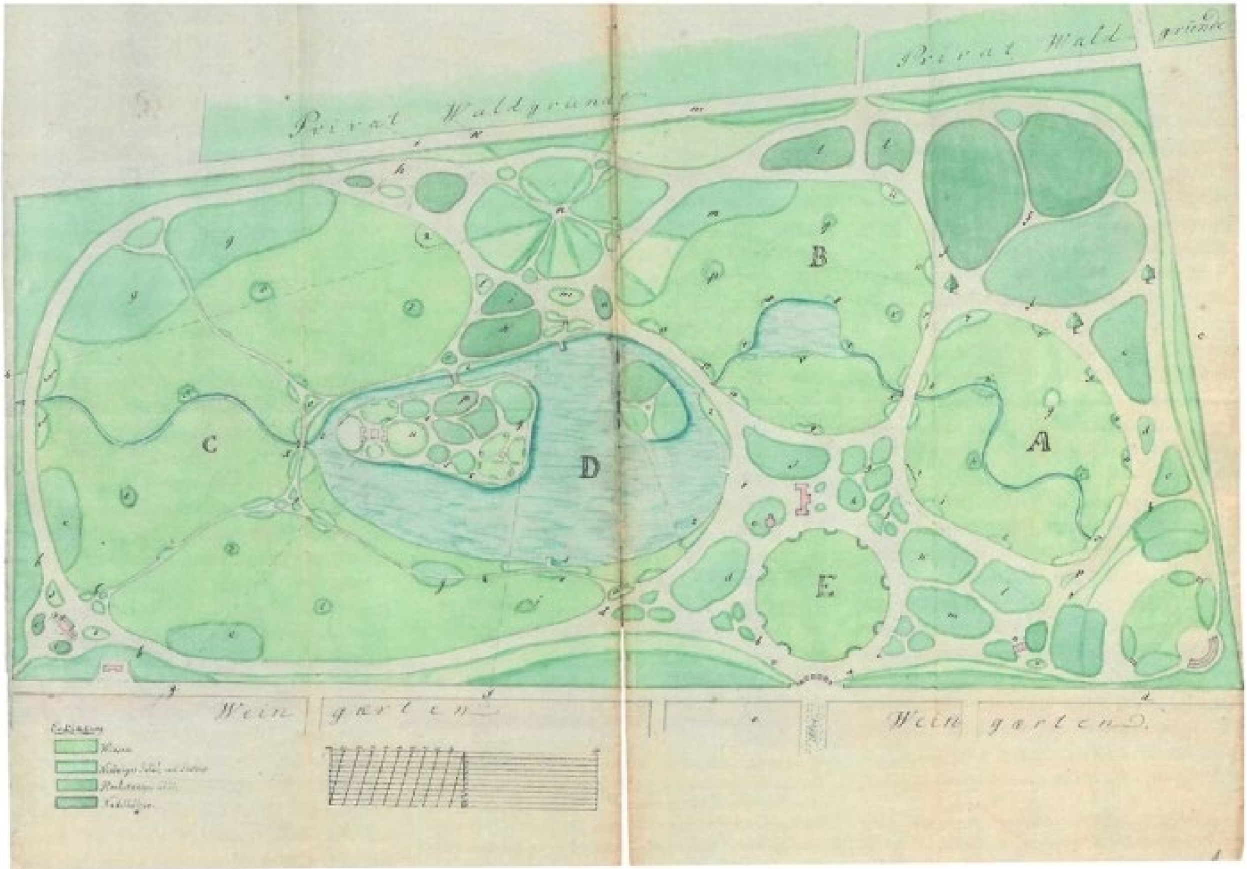
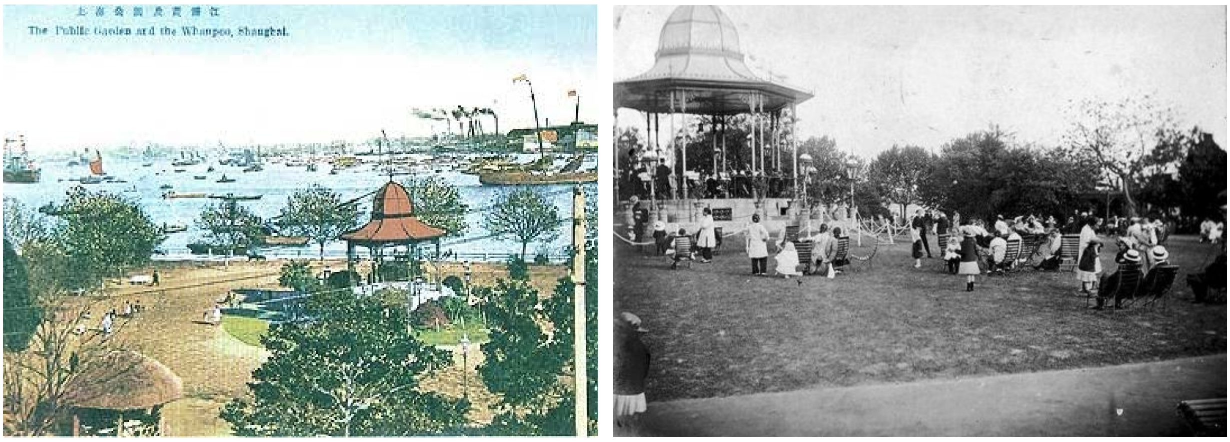
APPENDICES

Appendix 1: Zornberg's map of Maksimir Park in Zagreb, 1846 (Source: Wikipedia website[42]).

[42] Wikipedia website (https://en.wikipedia.org/wiki/Maksimir_Park). Accessed May 2023.



Appendix 2: Original plan of Városliget in Budapest by Henrik Nebbien, 1816 (Source: Jámbor (2019)).



Appendix 3: Public Garden in Shanghai in the 1920s (Source: Wikipedia website[43] and The Paper website[44], respectively).

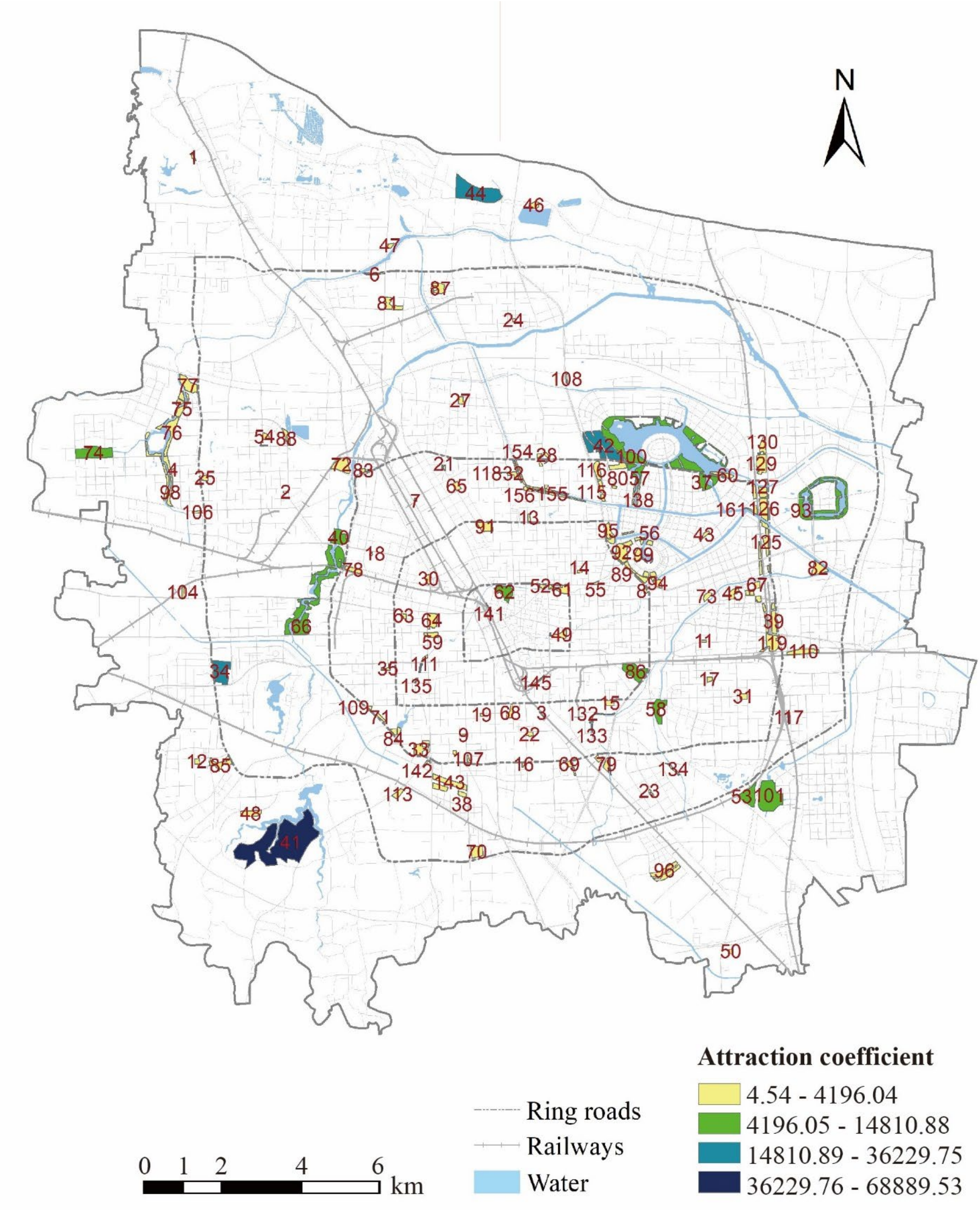
[43] Wikipedia website (https://en.wikipedia.org/wiki/Huangpu_Park). Accessed May 2023.
[44] The Paper website (https://www.thepaper.cn/newsDetail_forward_19538234). Accessed May 2023.

Appendix 4: Central Park in 1914 and present Zhongshan Park, originating from the Altar of Land and Grain in Beijing (Source: The People's Government of Beijing Municipality website[45] and China Daily website[46], respectively).

[45] The People's Government of Beijing Municipality website (https://baike.baidu.com/reference/6201625/533aYdO6cr3_z3kATP2LmKn5YCuXYN74v7LVWuNzzqIP0XOpX5nyFIo36d028PApEwTd_ptsL8QQmP-vVFQZraFNbu81QLUilWm7UTPAyb7u_99em9hDpolBXbNPw6yt). Accessed June 2023.

[46] China Daily website (http://ex.chinadaily.com.cn/exchange/partners/82/rss/channel/language/columns/v0m20b/stories/WS6556f82ca31090682a5eebe0.html). Accessed June 2023.



Appendix 5: Spatial distribution of park attraction coefficient in the central urban area of Zhengzhou (Source: Author).

Appendix 6: Attributes of UPPs in the central urban area of Zhengzhou (Source: Author).

Park code	Park size (m^2)	Park category	Facilities and amenities	Water feature	Tree canopy	Quality index	Attraction coefficient
1	26318.32	Other	0.75	0	1.0	0.68	300.11

2	10530.67	Other	1	0	1.0	0.89	157.03
3	10366.80	Other	0	0	0.5	0.03	4.54
4	11446.24	Other	0.5	0	0.5	0.45	85.34
5	23712.74	Other	0.25	1	0.5	0.34	135.21
6	34863.06	Other	0.25	0	0.5	0.24	137.61
7	12212.88	Other	0.5	0	0.5	0.45	91.06
8	19519.78	Other	0.25	0	0.5	0.24	77.05
9	11366.98	Other	0.5	0	1.0	0.47	89.73
10	15366.41	Other	0.25	0	0.5	0.24	60.65
11	13656.92	Community	0.5	0	1.0	0.47	215.62
12	39354.08	Community	0.5	0	1.0	0.47	621.34
13	27650.78	Community	0.75	1	1.0	0.79	727.65
14	20039.03	Community	0.75	0	1.0	0.68	457.01
15	64561.74	Community	1	1	0.5	0.97	2095.46
16	17979.14	Community	0.75	0	1.0	0.68	410.03
17	37859.73	Community	0.75	0	1.0	0.68	863.42
18	12148.56	Community	0.5	0	0.5	0.45	181.16
19	12240.51	Community	1	0	1.0	0.89	365.05
20	10757.33	Community	0.75	0	0.5	0.66	235.90
21	12981.40	Community	1	0	0.5	0.87	375.77
22	42602.28	Community	1	0	1.0	0.89	1270.54
23	19486.94	Community	0.5	0	1.0	0.47	307.67
24	11619.29	Community	0.25	0	0.5	0.24	91.72
25	49682.33	Community	0.5	0	0.5	0.45	740.85
26	21627.26	Community	0.75	0	0.5	0.66	474.27
27	54799.42	Community	0.5	1	0.5	0.55	1009.50
28	79512.48	Community	0.25	0	0.5	0.24	627.68
29	13701.73	Community	0.5	0	1.0	0.47	216.33
30	63531.26	Theme	1	1	0.5	0.97	2062.01
31	65852.33	Theme	0.5	0	0.5	0.45	981.97
32	72492.22	Theme	1	1	1.0	1.00	2416.41
33	164944.25	Theme	0.75	1	0.5	0.76	4196.04
34	521233.77	Theme	1	1	0.5	0.97	16917.51
35	35064.24	Theme	0.5	0	0.5	0.45	522.87
36	62371.08	Theme	0.5	1	0.5	0.55	1148.98
37	275735.68	Theme	0.75	1	0.5	0.76	7014.49
38	56735.14	Theme	0.5	1	0.5	0.55	1045.16
39	185646.20	Theme	0.5	0	0.5	0.45	2768.29
40	292925.73	Theme	1	1	0.5	0.97	9507.39
41	3739592.86	Theme	0.5	1	0.5	0.55	68889.53
42	909349.78	Theme	0.75	1	0.5	0.76	23133.10

43	47972.31	Theme	0.5	0	0.5	0.45	715.35
44	1116249.84	Theme	1	1	0.5	0.97	36229.75
45	106565.37	Theme	0.75	0	0.5	0.66	2336.89
46	84285.44	Theme	0.5	1	0.5	0.55	1552.68
47	37698.23	Theme	0.75	1	0.5	0.76	959.01
48	173074.49	Theme	0.25	0	0.5	0.24	1366.28
49	110188.86	Theme	0.75	0	1.0	0.68	2512.95
50	24783.68	Theme	0.25	1	0.5	0.34	282.64
51	19140.21	Theme	0.5	1	0.5	0.55	352.59
52	25877.69	Theme	0.5	0	1.0	0.47	408.57
53	352969.12	Theme	0.5	0	0.5	0.45	5263.36
54	57574.65	Theme	0.75	0	0.5	0.66	1262.56
55	17911.05	Theme	0.75	1	1.0	0.79	471.34
56	56913.19	Theme	0.5	1	0.5	0.55	1048.44
57	198717.68	Theme	0.75	1	0.5	0.76	5055.21
58	285069.87	Theme	0.5	1	1.0	0.58	5501.37
59	81267.31	Theme	1	1	0.5	0.97	2637.67
60	106843.25	Theme	0.75	1	0.5	0.76	2718.00
61	155410.93	Comprehensive	1	1	1.0	1.00	2590.18
62	277546.61	Comprehensive	1	1	1.0	1.00	4625.78
63	36967.33	Comprehensive	1	0	0.5	0.87	535.04
64	215388.12	Comprehensive	1	1	1.0	1.00	3589.80
65	63366.03	Comprehensive	1	1	1.0	1.00	1056.10
66	1607985.11	Comprehensive	0.5	1	0.5	0.55	14810.88
67	166574.36	Comprehensive	0.25	0	0.5	0.24	657.48
68	85388.88	Comprehensive	1	1	0.5	0.97	1385.72
69	43183.71	Comprehensive	0.5	0	1.0	0.47	340.90
70	195569.73	Comprehensive	1	1	0.5	0.97	3173.77
71	46137.70	Comprehensive	0.5	0	0.5	0.45	344.00
72	294752.33	Comprehensive	0.75	0	0.5	0.66	3231.84
73	63577.10	Comprehensive	0.25	0	0.5	0.24	250.94
74	591835.17	Comprehensive	0.75	1	0.5	0.76	7527.90
75	247312.47	Comprehensive	0.5	1	0.5	0.55	2277.95
76	443405.06	Comprehensive	0.5	1	0.5	0.55	4084.13
77	296748.65	Comprehensive	0.5	1	0.5	0.55	2733.30
78	105852.12	Comprehensive	0.75	0	0.5	0.66	1160.62
79	76290.54	Comprehensive	0.25	1	0.5	0.34	435.02
80	130349.10	Comprehensive	0.75	0	0.5	0.66	1429.22
81	162232.23	Comprehensive	0.75	1	1.0	0.79	2134.64
82	205123.62	Comprehensive	0.5	1	0.5	0.55	1889.36
83	45704.28	Comprehensive	0.75	0	0.5	0.66	501.13

84	79145.64	Comprehensive	0.75	1	0.5	0.76	1006.70
85	190031.90	Comprehensive	0	1	0.5	0.13	416.80
86	425337.91	Comprehensive	1	1	0.5	0.97	6902.53
87	165453.01	Comprehensive	0.75	1	0.5	0.76	2104.49
88	81818.54	Comprehensive	0.5	1	0.5	0.55	753.62
89	55832.43	Comprehensive	0.75	1	0.5	0.76	710.17
90	34478.51	Comprehensive	0.25	1	0.5	0.34	196.60
91	195331.90	Comprehensive	1	1	0.5	0.97	3169.91
92	343544.45	Comprehensive	0.5	1	0.5	0.55	3164.33
93	950711.27	Comprehensive	0.5	1	0.5	0.55	8756.84
94	253950.22	Comprehensive	0.5	1	0.5	0.55	2339.09
95	168814.86	Comprehensive	0.25	1	0.5	0.34	962.60
96	345687.57	Comprehensive	0.25	1	0.5	0.34	1971.14
97	55035.08	Comprehensive	0.75	1	0.5	0.76	700.02
98	333533.43	Comprehensive	0.5	1	0.5	0.55	3072.12
99	107538.14	Comprehensive	1	1	0.5	0.97	1745.16
100	2044892.47	Comprehensive	0.25	1	0.5	0.34	11660.15
101	919518.45	Comprehensive	0.5	1	0.5	0.55	8469.53
102	15714.94	Other	0.75	1	0.5	0.76	199.89
103	22231.38	Other	0.75	1	1.0	0.79	292.52
104	37510.34	Other	0.25	1	0.5	0.34	213.89
105	20264.54	Other	0.5	0	0.5	0.45	151.09
106	29420.37	Other	0.25	0	0.5	0.24	116.12
107	24371.97	Other	0.75	0	0.5	0.66	267.23
108	17152.48	Other	0.25	0	0.5	0.24	67.70
109	17377.98	Other	0.5	0	0.5	0.45	129.57
110	199134.43	Other	0.25	0	0.5	0.24	786.00
111	28741.79	Other	0.5	1	0.5	0.55	264.74
112	45323.12	Other	0.5	1	0.5	0.55	417.46
113	83683.95	Other	1	1	0.5	0.97	1358.05
114	35373.78	Other	0.25	0	0.5	0.24	139.62
115	65586.99	Other	0.25	0	0.5	0.24	258.88
116	155452.33	Other	0.75	0	0.5	0.66	1704.47
117	38944.96	Other	0.5	0	0.5	0.45	290.37
118	16191.94	Other	0.5	0	1.0	0.47	127.82
119	276723.26	Other	0.25	0	0.5	0.24	1092.25
120	50533.53	Other	0.25	0	1.0	0.26	221.61
121	30096.39	Other	0.25	0	0.5	0.24	118.79
122	16743.84	Other	0.25	0	0.5	0.24	66.09
123	54082.10	Other	0.25	0	0.5	0.24	213.47
124	48106.28	Other	0.25	0	0.5	0.24	189.88

125	143171.38	Other	0.25	0	0.5	0.24	565.11
126	240903.68	Other	0.25	1	0.5	0.34	1373.65
127	125994.40	Other	0.25	1	0.5	0.34	718.43
128	84893.73	Other	0.75	1	0.5	0.76	1079.81
129	267410.76	Other	0.25	0	0.5	0.24	1055.49
130	126087.69	Other	0.25	0	0.5	0.24	497.68
131	11681.06	Other	0.25	1	0.5	0.34	66.61
132	20476.79	Other	0.25	1	0.5	0.34	116.76
133	16989.46	Other	0.25	1	1.0	0.37	104.32
134	40079.94	Other	0.5	1	1.0	0.58	386.74
135	11184.10	Other	0.5	1	1.0	0.58	107.92
136	11063.98	Other	0.75	1	0.5	0.76	140.73
137	14396.97	Other	0.75	1	1.0	0.79	189.43
138	35899.04	Other	0.75	1	0.5	0.76	456.62
139	29082.95	Other	0.75	1	0.5	0.76	369.92
140	20806.68	Other	0.5	1	0.5	0.55	191.65
141	13624.11	Other	0.5	0	0.5	0.45	101.58
142	22828.04	Other	0.25	0	0.5	0.24	90.10
143	283719.93	Other	0.25	1	0.5	0.34	1617.79
144	119283.94	Other	0.25	1	0.5	0.34	680.17
145	34831.05	Other	0.5	0	0.5	0.45	259.69
146	12914.45	Other	0.25	0	1.0	0.26	56.64
147	13295.75	Other	0.25	0	0.5	0.24	52.48
148	31805.45	Other	0.5	1	0.5	0.55	292.95
149	24934.37	Other	0.5	1	0.5	0.55	229.67
150	16510.72	Other	0.5	1	1.0	0.58	159.31
151	26850.43	Other	0.5	1	0.5	0.55	247.31
152	29063.21	Other	0.5	1	0.5	0.55	267.70
153	21535.56	Other	0.5	1	0.5	0.55	198.36
154	27849.91	Other	0.5	1	1.0	0.58	268.73
155	39037.60	Other	0.5	1	0.5	0.55	359.57
156	38974.52	Other	0.5	1	0.5	0.55	358.99
157	30379.23	Other	0.5	1	1.0	0.58	293.13
158	19724.62	Other	0.5	1	0.5	0.55	181.68
159	33298.63	Other	0.5	1	1.0	0.58	321.30
160	29709.99	Other	0.5	1	0.5	0.55	273.65
161	68397.47	Other	0.5	1	0.5	0.55	630.00
162	31905.85	Other	0.5	1	0.5	0.55	293.88
163	18585.90	Other	0.25	1	1.0	0.37	114.13

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